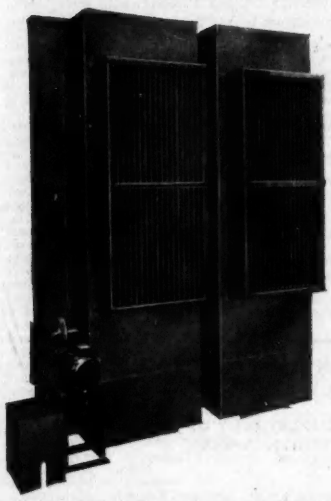
VISCO
AIR FILTRATION

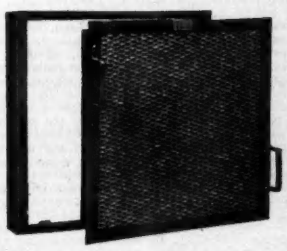


Two sections of Visco Patent Automatic "Reciprojet" Air Filter. These form part of a 12-section filter of 80,000 c.f.m. capacity being supplied for ventilation of a new central stores at a large steelworks.

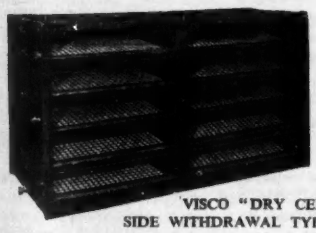
of thousands of "Visco" Air Filters are in regular use in this nd abroad for the ventilation of buildings, railway coaches, equipment, power stations, etc., and for filtering the intake sel engines, diesel/electric locomotives and air compressors. most purposes, our standard all-metal filter of the oil-wetted e most satisfactory. This filter consists of metal cells packed oated rings or ferrules which break up the air into innumerable ns without producing undue resistance to the air stream. The icles being relatively heavy are thrown against the oil-coated nd retained.

very dusty places as steelworks, cement and lime works, etc., "Reciprojet" Self-Cleaning Air Filter has distinct advantages. matic, has 2 stage filtration and will operate for long periods mum unskilled attention.

e an exceptionally high degree ation is required, as in labora- od factories, etc., "Visco" filtration is used. The air is d through a set of standard etted filters and then through filters.



STANDARD TYPE FILTER



VISCO "DRY CELL" FILTER
SIDE WITHDRAWAL TYPE

Consult us on your Air Filtration problems. Ask for "Visco Air Filters," List No. 521.

O ENGINEERING CO LTD. STAFFORD RD. CROYDON

THE ENGINEER

ESTABLISHED 1856

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AUGUST 20, 1954

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NOTICE TO READERS

All letters intended for insertion in 'The Engineer' or containing questions should be accompanied by the name and address of the writer, not necessarily for publication, but as a proof of good faith. No notice whatever can be taken of anonymous communications. No undertaking can be given to return drawings or manuscripts; correspondents are therefore requested to keep copies.

SUBSCRIPTIONS

U.K. & ABROAD £5. 10. 0. CANADA £5. 5. 0. annually including postage. Every subscriber is entitled to one FREE copy of the BUYERS GUIDE as published —extra copies 5s. each post free.

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LINEAGE RATE (Under 1 inch):—2s. 6d. per line of 6 words. Minimum 10s.

INCH RATE (1 inch and over):—Rates per insertion per single column inch—1 insertion—30s. 6 insertions—27s. 6d. 13 insertions—26s. 26 insertions—25s.

USE OF BOX NUMBER: The charge is 2s. including the cost of re-addressing replies, which are forwarded immediately on receipt. N.B. There is no Charge for Box Nos. under "Situations Wanted."

WORDING OF ADVERTISEMENTS: Approximately the first 25 letters of each advertisement are set in heavy type. Advertisers are therefore advised to begin their advertisements with the words they want emphasized.

Advertisements received by Mid-day Tuesday will appear in the issue of Friday the same week. Orders must be accompanied by a remittance.

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PUBLIC APPOINTMENTS

UNIVERSITY OF BIRMINGHAM

INSTITUTE FOR ENGINEERING PRODUCTION

ASSISTANT DIRECTOR AND STAFF TUTORS

Applications are invited for the following appointments :—

ONE ASSISTANT DIRECTOR, to be responsible to the Professor of Engineering Production for organising executive courses in work study, production planning, operational research and other management subjects, also lecturing and tutorial work in his own specialist field. Preferably applicants should be Engineering Graduates with experience in engineering production and industrial management positions.

The appointment would be made for two-three years, in the first instance, and at a salary of £1200–£1800 p.a., according to qualifications and experience.

THREE STAFF TUTORS, each responsible to the Assistant Director for lecturing, tutorial and case study work on one of the following subjects :—

(a) Work study (methods improvements, materials handling, work measurement).

(b) Production planning and management controls (procedural analysis).

(c) Operational research (statistical and mathematical methods).

Each tutor would require to have the appropriate training and specialist industrial experience in his own field. These appointments would be made for one to two years, in the first instance, at a salary of £1100–£1500, according to qualifications and experience. Leave of absence from an industrial company or other organisation for this period would be an acceptable arrangement.

Applications, giving full details of qualifications and experience, and the names of three referees, should be submitted in triplicate before 30th September, 1954, to the Registrar, The University, Edgbaston, Birmingham, 15. E5117

THE QUEEN'S UNIVERSITY OF BELFAST

RESIDENT ENGINEER

RESIDENT ENGINEER required to supervise under the consulting engineers, the installation of specialist services (heating, ventilation, electrical equipment, &c.) in a large block of scientific buildings in Belfast. The estimated date for completion of the contract is 31st March, 1958. There may then be an opportunity of appointment to a permanent post of maintenance engineer in the University. Salary not less than £600. Letters of application should specify age, education, qualifications, past experience, present post, salary expected, and should name not more than three referees. Applications should be received by 20th September by the undersigned, from whom further particulars can be obtained.

G. R. COWIE, M.A., LL.B.
E5055 Secretary.

COVENTRY TECHNICAL COLLEGE

MECHANICAL ENGINEERING DEPARTMENT

ASSISTANTS, GRADE A (FIVE VACANCIES)

Following full-time TEACHING STAFF required as soon as possible. Candidates should be Graduates or hold good technical qualifications ; previous teaching experience advantageous.

Mechanical Engineering Department, ASSISTANTS, Grade A (five vacancies). Applications considered from those experienced in some branch of mech., auto, aero, or production engineering.

Mathematics Department, ASSISTANT, Grade A, mainly for part-time O.N.C. and trades courses.

Salary, Burnham Technical Scales (Grade A Assistants, £450 by £18 to £725).—Application forms from Director of Education, Council House, Coventry. E5125

LONDON COUNTY COUNCIL

BRIXTON SCHOOL OF BUILDING

VISITING TEACHERS

VISITING TEACHERS for day classes in structural engineering subjects. Should be Corporate Members of the Institution of Civil Engineers or Institution of Structural Engineers, with appropriate experience of industry or professional practice and prepared to devote not less than one half day per week. Application forms from Secretary at School, Ferndale Road, S.W.4. (1056). E5053

LONDON ELECTRICITY BOARD

CHIEF ENGINEER'S DEPT.

STRUCTURAL DRAUGHTSMEN

Applications are invited for the above positions in the Construction branch of the Chief Engineer's Dept. in Central London.

Applicants for the positions of STRUCTURAL DRAUGHTSMEN in the Civil Engineer's Section should be familiar with building construction requirements, and have experience in detailing reinforced concrete or steel structures.

The posts are graded under Schedule "D" of the National Joint Board agreement, as Grade VI—£458 to £595 7s. per annum, inclusive of London Allowance. Commencing salary will be dependent upon qualifications and experience.

Application forms, obtainable from the Personnel Officer, 46, New Broad St., E.C.2, to be returned by 6th September, 1954. Please enclose addressed envelope and quote ref. V/1793/EE on envelope and all correspondence. E5081

PUBLIC APPOINTMENTS

NATIONAL COAL BOARD

NORTH-EASTERN DIVISION

APPOINTMENTS

Applications are invited for the following vacancies in the No. 4 Area of the North-Eastern Division at Grimethorpe, Nr. Barnsley :

CLERKS OF WORKS, Grade I—Salary Scale £625 by £25 to £775.

Applications are invited for the above appointment in connection with the N.C.B.'s present and future programme of civil engineering and building works involved in the surface reconstruction of various collieries in the area.

Applicants must have a wide practical knowledge and experience of building and allied trades and in the supervision and control of civil engineering and building contracts, and should also be capable of preparing estimates, drawing out plans and assisting in the measurements of quantities, if so required.

JUNIOR CIVIL ENGINEERS.

Applications are invited for two appointments as Junior Civil Engineers. Salary according to experience and qualifications.

The persons appointed will be required to act as resident engineer at a colliery site or sites, on large scale civil engineering reconstruction works within the area, under the Area Civil Engineer, or alternatively be required to serve at Area Headquarters as an assistant to the Area Civil Engineer.

Applicants should have had experience on the site control of large-scale civil engineering projects, and should in addition either hold the Associate Membership of the Institution of Civil Engineers, or a University Degree in Civil Engineering from a recognised University, and in addition, be actively engaged in preparing themselves to complete their Associate Membership in the near future. Consideration will also be given to candidates who have Sections A and B of the Associate Membership Examination of the Institution of Civil Engineers and are actively engaged in preparing themselves to complete their Associate Membership in the near future.

Applications for the above appointments, stating full name, address, age, qualifications, past and present appointments, together with details of experience, should be sent to the Area Administrative Officer, National Coal Board, North Eastern Division, No. 4 (Carlton) Area, Grimethorpe, Nr. Barnsley, by 6th September, 1954. It should be indicated clearly for which appointment application is made. E5070

ASSISTANT ENGINEER (PERMANENT WAY)

LONDON OFFICE

ASSISTANT ENGINEER (Permanent Way) required for their London office by the Crown Agents for Oversea Governments and Administrations. Basic salary scale £650 by £25 to £750 by £30 to £960 by £40 to £1000, plus extra duty allowance of approximately 8 per cent. The £650 minimum is linked to entry at age 25 and is subject to increase at the rate of one increment for each year above that age up to 34. Fully qualified officers at least 27 years old may be eligible for a special increase of £75 after two years' service. Engagement on unestablished terms with prospect of appointment to the established staff and of promotion. Candidates should have passed the Associate Membership Examination of the Institution of Civil Engineers, or of the Institution of Mechanical Engineers, or should hold an equivalent exempting Degree. They must have served in the Permanent Way Department of a Railway or with a firm manufacturing switch and crossing equipment, and must be good draughtsmen. They should have a detailed knowledge of such equipment and be capable of designing of station layouts and of making all calculations necessary for any type of turnout. A basic knowledge of railway signalling will also be an advantage.

Write to the Crown Agents, 4, Millbank, London, S.W.1, stating age, name in block letters, full qualifications and experience, and quote M2A/40381/E.H. E5135

COUNTY BOROUGH OF EAST HAM

APPOINTMENTS

QUANTITY SURVEYOR, Grade IV—£580-£625.

ENGINEERING ASSISTANT, Grade V—£620-£670.

SENIOR ARCHITECTURAL ASSISTANT, Grade VI—£695-£760.

ARCHITECTURAL ASSISTANT, Grade V—£620-£670.

London weighting is paid in addition. Salary in excess of the minima may be paid according to qualifications and experience.

Subsistence allowances may be granted over a reasonable period to persons appointed if unable to obtain suitable housing accommodation, necessitating the maintenance of two homes.

Further details and application forms returnable by 3rd September, 1954, from the Town Clerk, Town Hall, East Ham, E.6. E5068

LANCASHIRE RIVER BOARD

APPOINTMENT OF CHIEF ENGINEER

Applications are invited for the above APPOINTMENT.

Salary £1,750 by £50 to £2,000.

The post is superannuable and the appointment will be subject to the passing of a medical examination, and will be terminable by three months' notice on either side.

Applicants must state their professional qualifications and experience, and also give particulars of age, present and previous appointments, with salaries, and furnish the names and addresses of three persons to whom reference may be made. Applications must reach the undersigned by the 30th day of September, 1954. H. HOLMES,
Clerk of the Board,
48, West Cliff, Preston. E5069

PUBLIC APPOINTMENTS

PORT OF LONDON AUTHORITY

DRAUGHTSMEN

The Port of London Authority invite applications for a number of positions as DRAUGHTSMEN at the following scales of pay, inclusive of Pay Supplement :

The increments are annual, and commencing salaries within the scales are fixed according to qualifications and experience.

(a) 1st Class : £627 10s. per annum by £26 5s. to £758 15s. per annum.

(b) 2nd Class : £552 per annum by £23 by £21 to £596 per annum.

(c) 3rd Class : £425 10s. per annum by £17 5s. by £23 to £506 per annum.

Applicants should have experience in the following :—

(1) Civil Engineering Draughtsmen.—For (a) : the design and detailing of warehouses, sheds, offices, canteens and other buildings in reinforced concrete, steel and timber, connected with the Docks. Applicants must be able to work with the minimum of supervision.

For (b)* and (c): detailing such structures with or without supervision.

In all cases, maritime works experience and ability to make site surveys would be an advantage.

*This position is at Surrey Commerical Docks, S.E.16.

(2) Survey Draughtsmen.—For (b) : undertaking land and building surveys and plotting the results.

(3) Electrical Engineering Draughtsmen.—For (c) : making electrical wiring layouts for building work, under supervision.

Application forms may be obtained from the Establishment Officer, Port of London Authority, Trinity Square, London, E.C.3. E5096

GOVERNMENT OF NEW SOUTH WALES

CIVIL ENGINEERS FOR DEPARTMENT OF MAIN ROADS, NEW SOUTH WALES, AUSTRALIA

Applications are invited from CIVIL ENGINEERS for appointment to the staff of the Department of Main Roads, New South Wales. Candidates should either be Graduates of a British University or hold a qualification recognised as exemption from the examination of the Institution of Civil Engineers, or have passed that examination. On appointment applicants may be engaged at the Department's Head Office, Sydney, on the design of reinforced concrete and steel bridges or on main road construction and maintenance either in the metropolitan area or the country.

Commencing salary according to qualifications and experience will be within the range of £A914 to £A1073 per annum with annual progression to £A1267 per annum, subject to satisfactory service. Appointees will be eligible to contribute to State Superannuation Fund after six months. Single fare up to maximum £160 sterling will be paid to selected applicants subject to three years' service guarantee bond. Appointment will be subject to satisfactory medical examination and preference will be given to applicants not more than 30 years of age.

Applications should be made on forms obtainable from Agent-General for New South Wales, 56, Strand, W.C.2, by whom they will be received up to 20th September. E5153

ATOMIC ENERGY RESEARCH ESTABLISHMENT

HARWELL, BERKSHIRE

YOUNG ENGINEERS

Atomic Energy Research Establishment, Harwell, Berkshire, requires YOUNG ENGINEERS, up to the age of 32, in the grade of Technical Assistant for a wide range of duties including design, development, operation and maintenance of reactors, large electro-mechanical nuclear machines, chemical pilot plant, etc., and the operation and maintenance of special buildings and service installations. Selected candidates will gain experience in all aspects of nuclear engineering and on successful completion of training will be offered posts on the professional engineering staff. Candidates should hold an honours degree in mechanical or electrical engineering and should have served an engineering apprenticeship or postgraduate apprenticeship. Exceptionally, candidates may be considered with other qualifications exempting them from the examinations of the senior engineering institutions. Salary range £396 (at 21) to £718 per annum (men), less for women. Applications, quoting 2/103/133, to the Establishment Officer, A.E.R.E., by 3rd September, 1954. E5097

ESSEX RIVER BOARD

ASSISTANT ENGINEERS

Applications are invited for the following appointments :—

ASSISTANT ENGINEER, Grades A.P.T. V to VII, £620–£810.

Candidates for the appointment must be Chartered Civil Engineers with experience in the design and construction of maritime works. Knowledge of coast erosion and surface water drainage design and calculation would be an advantage.

ASSISTANT ENGINEER, Grades A.P.T. II to V, £520–£670.

Candidates for this appointment should have had experience in the design and construction of land drainage works and should preferably have passed Sections A and B of the Institution of Civil Engineers or hold a University Degree giving exemption therefrom.

Applications, giving details of experience and the names of two referees, should be submitted to the Engineer to the Board, Rivers House, Springfield Road, Chelmsford, not later than September 4th, 1954.

W. J. S. BEW,
E5145 Clerk of the Board

PUBLIC APPOINTMENTS

COMMONWEALTH OF AUSTRALIA

AUSTRALIAN ATOMIC ENERGY COMMISSION

RESEARCH VACANCIES

Applications are invited from CHEMICAL ENGINEERS, MECH ENGINEERS, METALLURGISTS for p the Commission's research establishment Australia.

Salaries : Appointments will be made in of Research Officer, Senior Research Principal Research Officer, the salary which, in Australian currency and inclus of-living allowance, are £854–£1262 p £1472 p.a. and £1564–£1812 p.a. respecti mencing salaries will be determined w ranges.

Duties : Research on problems of ato technology in the fields of chemistry, ch neering, mechanical engineering and Initially appointees may be required to w seas atomic energy establishments.

Qualifications : University Degree, with honours, and research experience in which applicants wish to be considered. should be British Commonwealth subje

Travel : First-class sea passages of app families to Sydney will be provided.

General conditions of service : As under the Atomic Energy Act, 1953. will be eligible to contribute to the Com Superannuation Fund or the Common vident Fund. Appointment will be cond satisfactory medical examination.

Applications : Applications should with the Secretary, Australian Atomic E mission, Box 4343, G.P.O., Sydney Australia, by 18th September, 1954, and (a) usual personal particulars, (b) war ser (c) qualifications, experience and publi names of referees who may be consulted mission, and (e) when available for monials (copies only) may be furnished.

Further information, if required, may from the Chief Scientific Liaison Officer, Scientific Liaison Office, Africa House, London, W.C.2.

P. C. GREENLA
E5159

COLNE VALLEY SEWERAGE

STAFF OF THE CHIEF RESI ENGINEER (SEWERS)

Applications are invited for the follow ments to the above staff for the supervis contracts in Hertfordshire :—

ASSISTANT ENGINEER (Sewers), £650–£850 per annum.

JUNIOR ENGINEERS (Sewers), £6–£10 10s. per week.

Duration of appointments 2 to 2½ year a month's notice on either side. Salari above scales to depend on experience a tions. Car allowance payable in appro stances. Housing at economic rental m able.

Applicants should have civil engineer of university or equivalent standard, an of civil engineering and setting out. A the senior appointment should also hav in supervising the construction of civil works, including main sewers, preferab and must be prepared to work in com

Applications, endorsed "Assistant E "Junior Engineer," giving full particu qualifications and experience, also th persons to whom reference can be m reach the undersigned not later than September, 1954, quoting the reference

CLERK OF THE BO
Colne Valley Sewer

16.8.54.

MINISTRY OF SUPPL

DRAUGHTSMEN

DRAUGHTSMEN required by Minis at various locations, with experience in ing classes of work : chemical plant, mech., automobile, precision instrume radar, electrical, electronics, structur jig and tool. At least 3 years' work and O.N.C. or equivalent. Starting pa £380 (age 20), £550 (age 28), rising to rates higher. Paid sick leave. 20 holiday, plus public holidays. 44-hou rally 5-day) including meal breaks. overtime. Appointments unestablished tunities to compete for pensionable po promotion to Leading Draughtsma (prov.), thence to Senior Draughtsma (prov.), and Chief Draughtsman, (prov.). Write, stating age, training experience to Ministry of Supply, Est. 519, Carlton Hotel, Haymarket, Londo

ANGLESEY COUNTY CO

COUNTY WATER DEPART

PUMPING SUPERINTEND

Applications invited for appointme ING SUPERINTENDENT in the C Department. Salary, Misc. Grade Rent-free house provided.

Applicants must have had experie tenance and running of electrically d plant and water treatment plant.

The appointment will be subject to of the Local Government Superannua one month's notice on either side, and of a medical examination.

Further details and application form Water Engineer, Glanaber, Llangef Closing date for applications 17th Se

THE ENGINEER

AUGUST 20, 1954

Atomic Weapons and Atomic Power Station Appointments

THE United Kingdom Atomic Energy Authority has announced the appointment of Mr. W. R. J. Cook, C.B., as deputy director of the Atomic Weapons Research Establishment, Aldermaston, Bucks, and of Mr. K. L. Stretch, M.A., as works manager at Calder Hall, Sellafield, Cumberland, where Great Britain's first atomic power station is under construction. Mr. Cook, who is forty-nine years of age and is at present chief of the Royal Naval Scientific Service, will move to his new post on September 1st, but for a short period thereafter he will continue to assist the Admiralty. He graduated at Bristol University in applied mathematics in 1925 and then, after two years' fundamental research in theoretical physics, leading to the award of M.Sc., he entered the Civil Service in 1928. He held, in turn, a number of appointments in the projectile development establishment at Woolwich and elsewhere, and became chief superintendent of the Guided Projectile Establishment at Westcott, in 1946. From 1947 to 1950 he was Director of Physical Research, Admiralty, and he was appointed chief of the Royal Naval Scientific Service in 1950. Mr. K. L. Stretch, who is thirty-seven years of age, graduated at King's College, Cambridge, and started an engineering apprenticeship with Mather and Platt, Ltd., Manchester, in 1939, but soon afterwards he was commissioned in the Royal Artillery. In 1942 he was transferred to the Royal Electrical and Mechanical Engineers and later saw service in France and Germany. After being demobilised in 1946, he returned to Mather and Platt, Ltd., where he completed his training and then worked in the company's research department until 1948, when he joined Imperial Chemical Industries, Ltd., as instrument manager at the Hillhouse Works (General Chemicals Division), near Blackpool. In 1949 he became deputy works engineer at Hillhouse and in December, 1951, he was transferred to the company's Salt Division as design engineer. Mr. Stretch is a barrister-at-law and an associate member of the three Institutions—Civil, Mechanical and Electrical Engineers.

Report on a Derailment in North Queensferry Tunnel

THE Ministry of Transport and Civil Aviation has now published its report on the derailment which occurred in the North Queensferry tunnel near the Forth Bridge on March 7th last. The report states that there is no doubt that the express stopped in the tunnel owing to the engine wheels slipping on the new rails and that it ran backwards through the catch siding. The engine was steaming well with the vacuum brake and sanding gear working properly and in normal circumstances little difficulty should have been experienced. The load was, however, slightly more than the authorised maximum and the speed had been reduced to 20 m.p.h. on account of the restriction over the newly laid rails, which experience has shown are more liable to cause slipping than worn ones. The strong wind blowing across the track would also have slightly increased the train resistance round the curve. Speed continued to drop till finally the train stopped altogether and began running backwards. The driver could not be blamed for mishandling the engine, the report continues, nor for failing to notice the run-back. The records show that in just over two years, thirty other trains, including three passenger trains, have failed to negotiate the steep Forth Bridge incline. Serious accidents due to trains stalling and running backwards in tunnels unbeknown to the drivers have occurred before, as, for example, at King's Cross on February 4, 1945, and at Glasgow, Queen Street, on October 12, 1928. Lights have since been provided in both these tunnels as well as in some others on steep inclines, and, provided they are spaced sufficiently close together, they can be of great assistance to a driver at a critical time. A scheme is being prepared for lighting both the Inverkeithing and North Queensferry tunnels, but the report recommends that the conditions in other tunnels on heavily worked inclines should also be reviewed with the object of providing lights should the circumstances warrant them. The resiting of the catch points is also envisaged at the North Queensferry tunnel.

Twenty-First Radio Show

THE twenty-first radio show, organised by the Radio Industry Council, will be held at Earl's Court, London, from August 25th to September 4th. More than fifty-five sound and television programmes will be broadcast from the show and continuous television programmes will be produced on the closed circuit serving 409 receivers in the exhibition. Forty manufacturers will show receivers for sound and television, including thirteen-channel sets for the new commercial television services. Underwater television will be among the demonstrations given by the Royal Navy. On the Army stand there will be a recording studio where members of the public will be able to record messages for relatives serving abroad in any of the three Armed Services. The Royal Air Force will demonstrate some of the problems of supersonic flight with the help of a jet aircraft cockpit equipped with typical instrumentation, including radar and other devices for navigation and safe landing. Industrial and scientific applications of electronic apparatus will be covered by a group of thirty-one exhibits arranged by the Radio Industry Council, and this part of the show will include a display designed to depict the technical training facilities that the industry offers to its recruits.

National Traffic Census

ON Monday, August 16th, highway authorities throughout the country, working in co-operation with the Ministry of Transport and Civil Aviation, began the first comprehensive traffic census to be held since 1938. The census is being taken on all trunk and class I roads, and is being carried out by about 20,000 enumerators stationed at between 5000 and 6000 points. In a few cases, counts may be taken during a different week from that chosen for the rest of the country, as for instance, where some special local event may affect normal traffic conditions. Some local authorities may also have found it necessary, because of staff difficulties, to spread the counts over two weeks, but all the counts will cover seven days. Most of the counts are for sixteen hours each day, from 6 a.m. to 10 p.m., but at some of the more important points, a night count is to be taken in addition. With certain variations, the census points are the same as those used in 1938. Altogether, twenty-three classes, including sub-divisions, of vehicles are to be enumerated. The chief changes in these compared with 1938 are the sub-division of motor-cycles into solo, combinations and motor-assisted pedal cycles ; a reduction in the categories of buses and coaches from four to two ; and the separation of light vans and lorries (up to 30 cwt) from the heavier vans and lorries. Unusual traffic, such as steam rollers, animals ridden and led, military formations and tanks, will not be recorded, nor will pedestrian counts be taken. Sample traffic censuses were carried out in 1950 and 1953. The first was taken at 270 widely distributed points on trunk, class I and class II roads throughout England, Scotland and Wales, and showed an increase in traffic over 1938 of about 6 per cent. The second census, taken at 100 points on trunk and class I roads, showed an increase of 24 per cent in mechanically propelled vehicles as compared with 1938. The analysis of the data which previously was carried out by clerks and partly by the local authorities and at Ministry headquarters, will this year be done by the Ministry. The information will be transferred to punched cards, and the subsequent analysis will be done by machines.

Model Engineer Exhibition

THE annual Model Engineer Exhibition was opened on August 18th by Prince Bernhard of the Netherlands at the New Horticultural Hall, Westminster. It will remain open, Sunday excepted, until August 28th. This is the twenty-ninth year of the exhibition, and its accustomed standards of craftsmanship are fully maintained in the nearly 300 models which are being shown. The model maker's enthusiasm for steam is exemplified by the many exhibits of railway locomotives and road traction engines, as well as those of stationary and marine engines. A great variety of ships' models is on view, ranging from old sailing ships and men-o'-war (such as the one built by a French prisoner of the Napoleonic era), to a sectional model of the U.S.N. atomic submarine "Nautilus," and including such diverse examples as a Formosan bamboo raft and a one-quarter scale 14ft naval dinghy. Many aircraft models have been entered, both flying and non-flying, some of the latter providing interesting glimpses into the near and distant future. There is again a flying arena, consisting of a wire cage, 14ft in diameter, where control wire models reach speeds of up to 100 m.p.h., and a marine tank where radio-controlled ships and speedboats are being shown in action. Among exhibits of a general nature are scale models of machine tools, internal combustion engines, clocks, road vehicles, old and modern, full-size machine tools for the home workshop, and engineers' hand tools. Clubs and societies concerned with the various branches of the art are represented, and there is a very full trade show, as well as a demonstration area where experts explain their special techniques, such as the scaling of hulls of fibre glass construction.

Boerasirie Extension Scheme in British Guiana

A FIVE-YEAR contract to carry out the Boerasirie extension scheme, for a total of approximately 6 million dollars, has been awarded by the British Guiana Government, with the assent of the Colonial Office, to Sir Lindsay Parkinson and Co., Ltd. The work involves the excavation of approximately 8¼ million cubic yards in 36 miles of conservancy dam, and 1,310 miles of canals and drainage trenches. By the time the work is completed, the contractor will also have built about 152 large and small reinforced concrete headworks, sluices and bridges. The scheme is intended to provide drainage and irrigation of an area of 129,763 acres on the coastlands between the Essequibo and Demerara rivers. A special machine for consolidating and shaping the dams has been designed and is being developed by the contractor with the aid of United Kingdom firms. As part of the contract, arrangements are being made for some thirty Guianese to undergo training in the United Kingdom in civil and mechanical engineering and cost accounting in order to fit them for general superintendence of future works in the colony, when the lack of skilled supervisory personnel has been the main obstacle to satisfactory progress.

Some Notes on the Development of Fairground Machinery

By P. W. BRADLEY

No. VI—(*Continued from page* 221, *August* 13*th*)

This article deals with that class of circular riding machine having a revolving section or sections, which are located to the centre of rotation by radial arms, but whose weight is borne wholly or partially by wheels at the periphery running on a circular tram ; in some cases the tram is undulating.

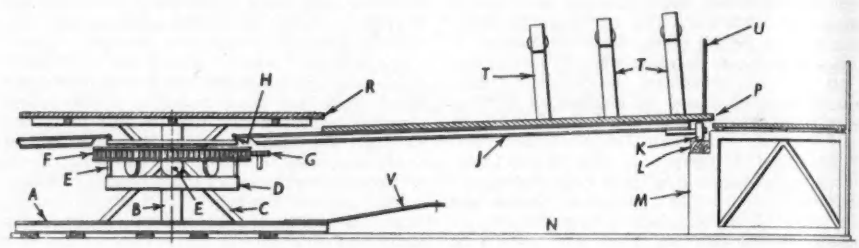
A PREVIOUS article in this series traced in some detail the earlier development of the circular track riding machine, but was confined to those varieties having two concentric rails which (by virtue either of being grooved, or of having flanged wheels running on them) acted not only as load carriers but also as guides. An obvious alternative was to locate the revolving section or sections to the centre of rotation by means of radial arms, or "swifts," so that only one circular rail was required, and that merely as a weight carrier. For some unknown reason, this principle found comparatively little favour during the earlier stages of roundabout development ; but it has been extensively utilised in more recent years.

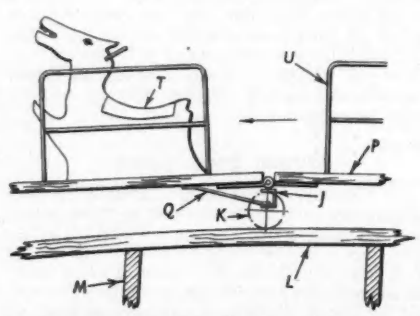
The earliest record which the author has traced of a machine so constructed is a patent taken out by Frederick Savage in 1881 for a modified "Sea-on-Land," of flat track design as before, but having a single tram within the boat circle. A series of radial swifts was secured to a sleeve running on the vertical pole close to its lower end ; and they were connected together by quarterings to form a rigid polygonal frame. A series of wheels near the periphery ran on the single tram ; and the frame also carried the horizontal rocking axes for the boats. The specification additionally covers two forms of rocking motion alternative to that previously described. One involved the provision of a second circular rail, concentric with and alongside the main tram, but undulating. Rollers running on this rail actuated cranks which imparted the desired motion to the boats. The other was essentially as in the Savage-Sanger 1880 design, but the spur reduction stage was eliminated. Very large tram wheels, apparently 5ft or more in diameter, were used instead.

An important early application of the single tram principle was the "Bicycle Roundabout." Little data have survived on these machines, but they are known to have been popular at about the turn of the century. Most of the designs incorporated a number of connected single or tandem pedal bicycles running on their own wheels on a circular flat tram, and constrained to follow a circular course by means of locating rods to the centre. The cycles were permanently set at a slight inward inclination and a brake block could be applied to the tram by a lever at the centre of the machine. Other versions incorporated a steam centre engine, the pedals being dummy. There were various elaborations of the basic design : one, patented in 1901 by John Collins, incorporated two independent concentric circles of pedal bicycles, so that racing was possible. Widely varying capabilities of the riders on a bicycle roundabout at any one time led Savages to devise a pawl and ratchet "free-wheel" hub, and this was fitted to machines of their manufacture, but unfortunately the enormous potential value of the device for cycles in conventional road use was not appreciated at the time.

The next important single-track machine, the "Caterpillar," was the pioneer of a series of devices utilising a single undulating tram. Patented (in the final form) in 1923 by Hyla F. Maynes, of Tioga, Pennsylvania, it has enjoyed a fair measure of popularity in this country and several examples are still travelling. A spider running on a central vertical axis carries twenty-four radial swifts, pivoted so that they can rise and fall according to the undulation of the tram. The tram wheel bearings are fitted to the outer ends of the swifts and twenty-four cars are carried between them. A loading platform surrounds the tram and follows its undulations. Drive is on the "Big Wheel" principle ; an endless cable engaging grooved carriers attached to the underside of the swifts and at one point passing round driving and tensioning pulleys. These, together with the electric motor and reduction gearing, are accommodated under one of the "hills." A semi-circular folding canvas canopy is provided; it can be operated whilst the machine is running, and in the extended position it envelops the whole train of cars, giving the appearance of a giant, endless caterpillar. This canopy is carried on a series of twenty-four fan-like supports accommodated in the gaps between the cars. From a sheave incorporated in each "fan," a double cable extends to a drum carried on the central vertical axis of the machine. At the start of each ride, the canopy lies in the folded position, inside the car circle, the "fans" being held in the collapsed position by means of springs. The central drum rotates with the cars, so keeping the canopy cables taut. When full speed is reached the central drum is declutched by the operator and locked to the vertical axis. Continued rotation of the cars then causes the canopy cables to wind round the central drum, turning the "fan" sheaves and closing the canopy against the action of the springs. When fully closed (the action occupying about five-eighths of a circuit) the central drum is automatically unlocked from the axis, and again revolved with the swifts. Folding of the canopy is effected by declutching the drum, so that the springs are free to act. Additionally, closing cables are provided. The control gear for the central drum is ingenious but necessarily complicated ; it is, however, described in detail in the patent specification (No. 208505), which illustrates the complete machine almost exactly "as built." Before leaving the caterpillar it may be noted that the "Big Wheel" style of rope drive was not used on subsequent machines, all of which were either centre-driven or had motors to some of the track wheels.

The next of the series of machines dependent on a single undulating tram was the "Noah's Ark," introduced from the Continent in 1930 or thereabouts. Its manufacture was taken up in this country by R. J. Lakin and by Orton and Spooner, and a little later by Lang Wheels (Manufacturing), Ltd., of Uxbridge, and by 1935 it had achieved a numerical popularity second only to that of the "dodgems." Fig. 22 shows the essentials of a typical "Noah's Ark" in part cross-section. The centre turntable and driving gear form a self-contained unit built on a rectangular steel base frame *A*. The fixed central column *B* is strutted by four diagonal girders *C*, with brackets which carry a circular roller track *D*. The cheese-wheel carries a series of steel rollers *E* which run on this track, and are surrounded by the lantern wheel *F* driven from an electric motor via belt and bevel gear reduction drives to the pinion *G*. Within the cheese wheel further rollers on vertical axes engage a sleeve on the column *B*. An upper annular extension of the lantern wheel carries by means of knuckle joints *H* a series of radial channel girders *J*, the outer ends of which carry small rubber-tyred wheels *K* running on the undulating single tram *L*. This is carried on inward extensions of the "gates" *M* which vary in height and support the undulating loading platform or walkway. A "spider bottom" *N* locates the gates to the base frame *A*, and also simplifies levelling. The girders *J* are spaced apart by a series of segmental platforms *P* connected pivotally to the girders and to each other by long rods inserted through a series of eyes, as shown in Fig. 23. The lower flange of the girder is linked to the platform ahead by means of a drag link *Q*. By this means a virtually unbroken revolving circular platform is provided ; both the linear speed and degree of undulation vary from a





Figs. 22 and 23—The "Noah's Ark" machine introduced from the Continent about twenty-four years ago. It has become one of the basic English fairground rides in place of the "Galloping Horses" and "Switchback" (or Scenic Railway)

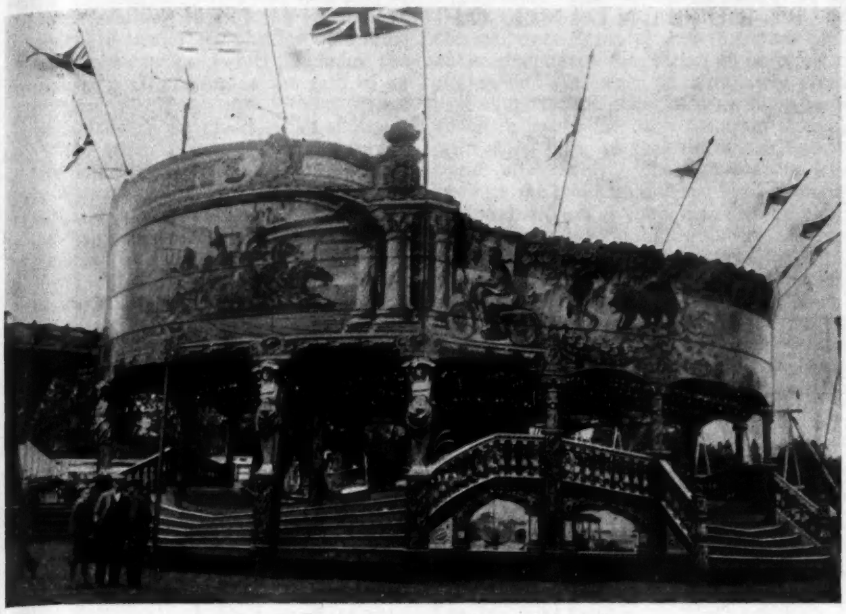


Fig. 24—A particularly ornate example of the "Noah's Ark," built by Lakins in 1937. Including the four-wheeled centre truck it makes five large loads for the road

minimum at the centre (enabling fare-collectors to step onto the platform from a stationary fixed circular island *R*) to a maximum at the periphery. Towards the periphery mounts *T* are provided, usually three abreast; they are ridden astride and are provided with hand grips. Safety rails *U* are fitted to each platform segment. The controller for the motor is usually fitted on the fixed platform. The whole is surrounded by uprights with hand rails and surmounted by a conical tilt carried on rafters extending radially from a vertical pole built from the central island.

The running speed of these machines is approximately 11 r.p.m., clockwise rotation being universal, and the difference in track level at highest and lowest points being about 2ft. The decorative features improved with the years; the earliest examples were rather austere, but elaborate pillared porch entrances were introduced at a later stage. The most elaborate examples of all were two produced in 1937 by Lakin, and styled "Coronation Speedway." One of them is illustrated in Fig. 24.

The style of mounts used has also changed with the years and the assorted wild animals fitted to the imported and earlier English sets led to the adoption of the name "Noah's Ark," which has remained. With all the external alterations which have been made there have been few mechanical changes. In 1938 Orton and Spooner produced a machine in which the centre drive was replaced by electric motors fitted under the seats of the chariots; but as far as is known the experiment was not repeated. A year or two previously the centre design underwent an alteration in being built as a four-wheeled road truck with a central well; this involved no difficulty, since the road wheels could be accommodated under the "high" positions of the platform. This vehicle afforded stowage space for the gates and some other components and, more important, obviated lifting. With the earlier pattern represented in Fig. 22, it was necessary to raise one end by means of block tackle and sheer legs, so that the axle of a pair of road wheels could be inserted under the base *A*. The centre then travelled as a two-wheeled trailer, a suitable drawbar *V* being permanently attached to the frame. In addition to the centre truck, of whichever form, all "Arks" employ one large open vehicle for the girders and platform sections, sometimes with a simple platform body, but usually having a frame. Thus the girders, required before the platforms when building and vice versa when packing, could be stowed at a convenient height for handling. The rest is packed in enclosed vehicles varying in number from one to three.

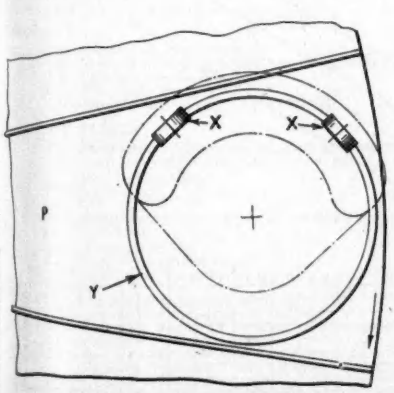


Fig. 25—The "Waltzer," a development of the "Noah's Ark," in which three distinct motions are compounded—circular travel of the platform, vertical undulation and tilting of the platform and rotation of the car about its vertical axis

A direct and obvious development of the "Noah's Ark" lay in the fitting of movable cars to the platform in place of fixed mounts. Accordingly, 1933 saw the introduction of the "Waltzer," in which cars somewhat resembling those of a "Swirl" were pivoted on vertical axes on alternate platform segments, as shown in plan in Fig. 25. Weight-carrying rollers *X* ran on flat circular tracks *Y* affixed to the platform surfaces, and supported the out-of-balance load. Friction brakes, to control the rotation, were operated by hand levers accessible from the central fixed island—this brake gear was the subject of a joint patent by R. J. Lakin and C. W. R. Thurston. A more varied motion was given to the car by arranging a portion (usually one-quarter) of the tram at a uniform high level and providing two hills and three dips in the undulating remainder. It was also obviously desirable to have alternate wide (car-carrying) and narrow (intermediate) platform segments. In other respects, except speed, which is about 8 r.p.m. instead of 11 r.p.m., the "Waltzer" machine is essentially identical to the "Ark." It was not numerically strong before the war; London fairgrounds, for instance, never saw any example except occasionally the pioneer machine owned by Mr. C. W. R. Thurston, part inventor of the brake gear. Since the war, more interest has been taken in this novelty; several new sets have been built and numerous "Arks" permanently converted. There is also at least one instance of a readily convertible machine; a valuable asset when large "established" fairs and small private ones alternate.

In the machines so far described, the segmental platforms serve to keep the girders in approximately a radial position. The knuckle joints accommodate the slight relative movement when a segment connecting two girders moves from a horizontal to an inclined position and any tendency of the periphery to "lag" is resisted by the hinges between segments. In machines without segmental platforms or their equivalent, other arrangements have to be made and in the first of these, the "Mont Blanc" or "Airways," the problem was accentuated by the fact that the nature of the ride demanded much steeper hills than a "Noah's Ark."

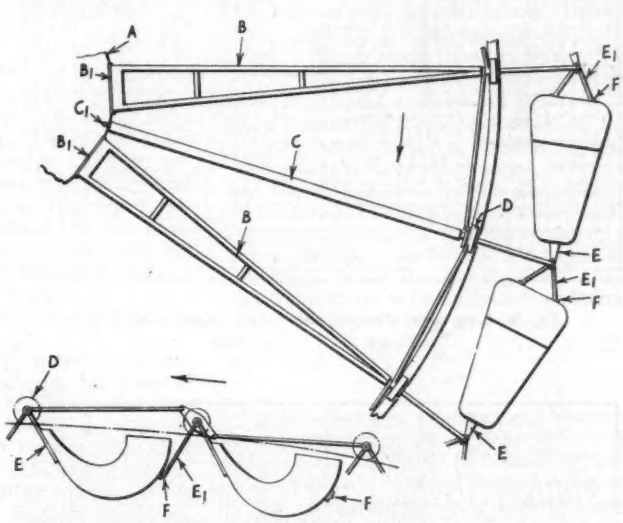


Fig. 26—For the action of the "Mont Blanc" or "Airways" the double-armed crank linkage shown was devised to replace a coiled spring arrangement originally used

The "Mont Blanc" was introduced to this country from the Continent in 1932 or thereabouts, and its main features are the subject of a patent by Octave Rouge and Sassoon Sopher. R. J. Lakin acquired the building rights for this country and in one important respect he improved on the original design. In spite of its bulk and weight, his "Airways" was a success and a number

BEHAVIOUR IN PURE BENDING OF BOX GIRDERS

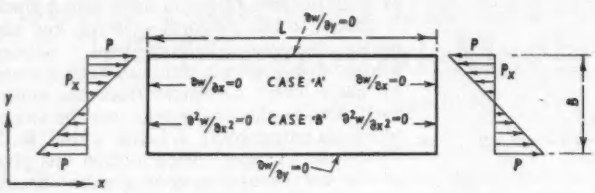


Fig. 1

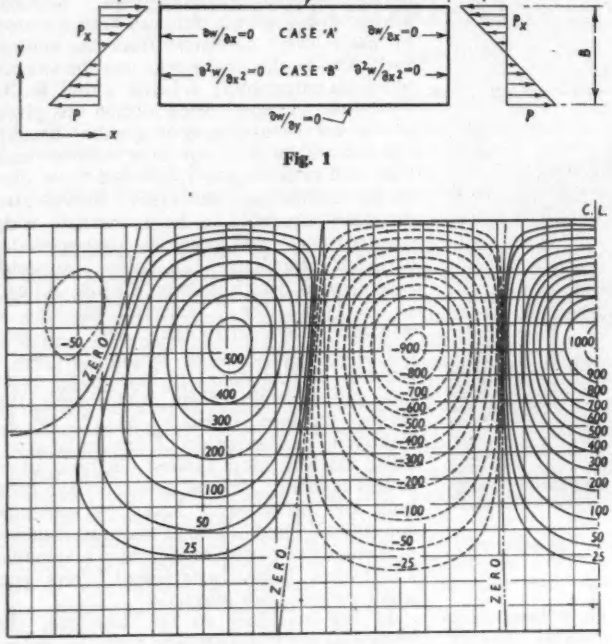


Fig. 2—Critical mode, all edges clamped (case "A")
$\lambda=385$ $a=B/16$

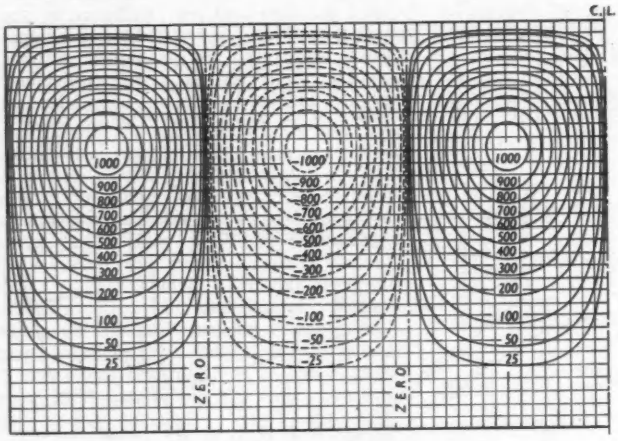


Fig. 3—Long edges clamped, short edges pinned (case "B")
$\lambda=390$ $a=B/32$

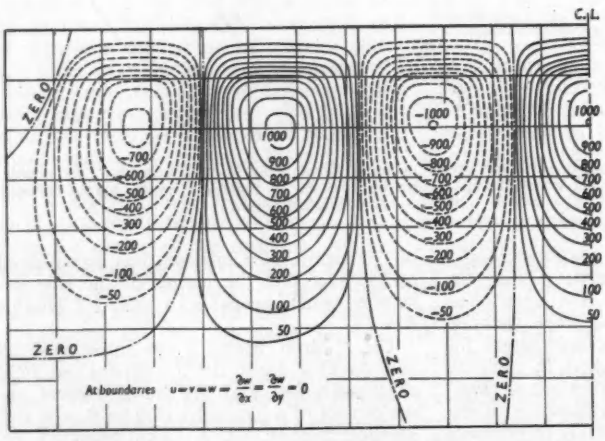


Fig. 4—Finite deflections, all edges clamped (case "A")
$\lambda=475$ $a=B/8$ $1000=0\cdot764h$

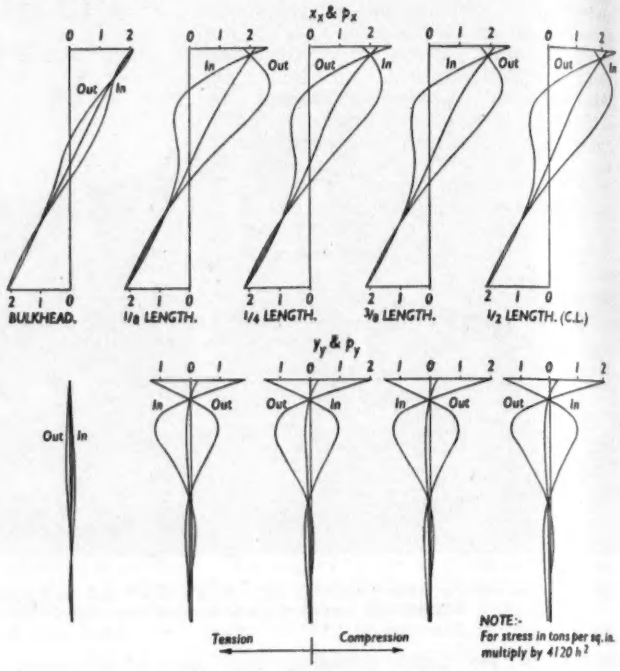


Fig. 5—Theoretical stress distributions

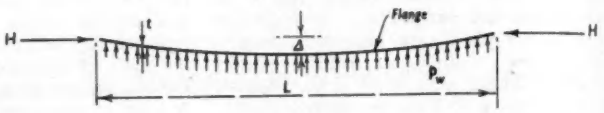
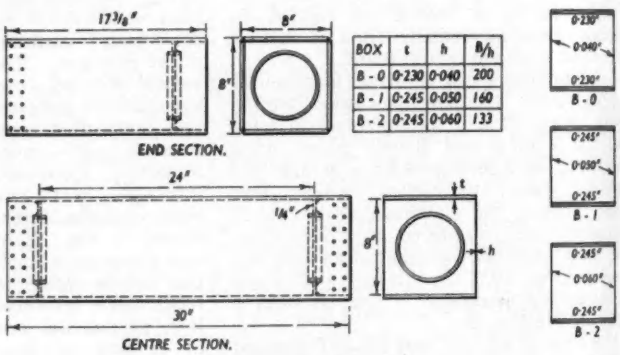


Fig. 6



BOX	t	h	B/h
B - 0	0·230	0·040	200
B - 1	0·245	0·050	160
B - 2	0·245	0·060	133

Fig. 7—Girder details

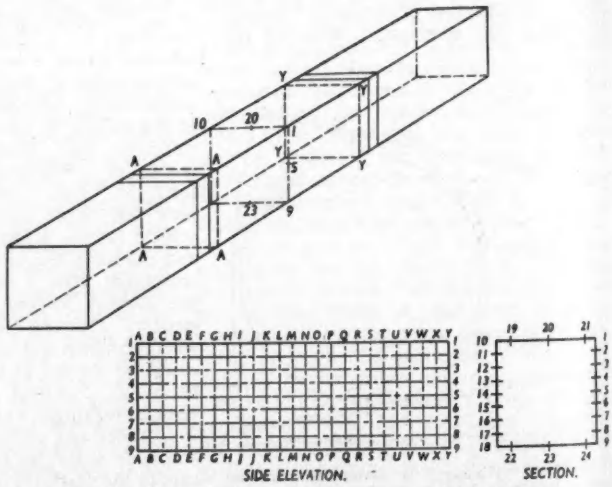


Fig. 8—Reference grid for unstiffened girder with thin webs

were built. Fig. 26 shows the essentials in plan and elevation. The centre turntable *A* is mounted in an elevated position on a four-wheeled centre truck (which includes the driving gear). It carries, in the case of an eighteen-car machine, nine braced girder swifts *B* mounted on pivots B_1 of sufficient length and strength to transmit the torque to the periphery. The nine intermediate swifts *C* are carried on knuckle joints C_1 and in Lakin-built examples they are coupled to the neighbouring girder swifts by the double-arm crank and pair of links shown in the lower drawing. In the original design a less satisfactory coiled spring arrangement was employed. The swifts extend beyond their rubber-tyred tram wheels *D* to carry the car suspension pivots, which allow of "swinging-out" under the action of centrifugal force. The suspension bars *E* at the fronts of the cars are rigidly attached, but the rear ones E_1 are pivoted to the car at *F*, to accommodate the variation in pitch of the swifts. In order to alternately create and eliminate the effect of centrifugal force, so as to swing the cars, the tram is made with steep hills, so that the linear velocity varies appreciably. The difference in level between the two high and the two low points is about 6ft, on a tram diameter of about 35ft. The conventional walkway and uprights supporting inclined rafters for a top tilt are provided and structurally the machine is built on the same principles as a "Noah's Ark"; the chief differences lie in the proportions and in the fact that the undulating walkway is at a lower (instead of slightly higher) level than the tram.

(To be continued)

Behaviour in Pure Bending of Box Girders

By J. C. CHAPMAN, Ph.D., A.M.I.C.E.*

The work described forms part of a more general investigation into the behaviour of thin-walled box girders and was designed to study the effect of buckling in the webs without the added complication of flange buckling. The theoretical analysis is mainly devoted to the study of an initially flat rectangular plate sustaining end forces which vary linearly from compression at one edge to an equal tension at the other. Southwell's relaxation method has been used to find the critical thrust and mode for two different boundary assumptions; also the mode and stress distribution have been found for a thrust 40 per cent greater than the critical, taking account of the extensional forces due to buckling. The experimental work comprised pure bending tests on three girders, the centre sections of which were 24in long by 8in square, the webs being 0·04in, 0·05in and 0·06in thick. Stress distributions around each girder were measured by means of electrical resistance strain gauges, and deflection contours were found for the webs. In the case of one web, the stress distribution has been calculated from measured deflections. It is concluded that, although buckling does occur from the first application of load, the effectiveness of the webs is not seriously affected. The theoretical solutions obtained are not in close agreement with the experimental results.

THE tests described form part of a general investigation into the behaviour of box girders under various loading conditions. Some of the girders are stiffened and some unstiffened. The unstiffened girders, 24in long and 8in square, are of three types :—

(1) Having thin flanges and thick webs.
(2) Having thick flanges and thin webs.
(3) Having equally thin flanges and webs.

The object of the tests on the first two types of girder was to study separately the effects of flange and web buckling without the complication of interaction between the two types of instability. This article is concerned only with the unstiffened boxes having thin webs, when subjected to pure bending.

As the thin webs contribute little to the strength of the section, non-linearity of stress distribution arising from buckling in the webs will not affect appreciably the equality of stress in the two flanges, which are themselves too thick to buckle. For the theoretical treatment the webs have therefore been considered as plates initially sustaining end thrusts which vary linearly from compression at one edge to a tension of equal magnitude at the other.

It was required not only to find the critical stress and mode of buckling, but also to study the displacements and stresses obtaining when deflections became appreciable. An orthodox solution of the equations thus involved presents great difficulty, even for simple cases having uniform loading conditions and a symmetrical mode of distortion, and it was therefore decided to use the relaxation method.‡ The critical thrust and mode for the webs have been found, using two different boundary assumptions; in addition, deflections and stresses have been calculated at a particular load for one of these assumptions, taking account of the extensional forces arising from the finite deflections.

Experiments have been carried out on three girders, for which the stress distributions at the centre sections and the web deflections have been measured. The possibility of deducing stresses from measured deflections has also been investigated.

In general there is little agreement between theoretical and experimental results.

Theory

The loading conditions considered are shown in Fig. 1, the plate being taken as initially flat.

Most attention is paid to the condition where all edges are clamped (known as "case A"), but an "infinitesimal deflection" solution is also obtained for the case where the short edges are free to rotate ("case B"), in order that a comparison may be made with the orthodox solution of Leggett.§ The possibility of collapse of the webs, due to the vertical pressure arising from the curvature of the flanges, is also considered.

Infinitesimal Deflections—Critical Mode and Thrust

Provided that the deflections are infinitesimal, and that as a consequence the membrane forces due to buckling may be neglected, the buckling configuration is governed by the equation :—

$$\nabla^4 w = -\frac{1}{D}\left(P_x\frac{\partial^2 w}{\partial x^2}+P_y\frac{\partial^2 w}{\partial y^2}+2S\frac{\partial^2 w}{\partial x\partial y}\right).$$

For the loading conditions considered

$$P_y = S = 0$$

and

$$\nabla^4 w = -\frac{P_x}{D}\cdot\frac{\partial^2 w}{\partial x^2}$$

which may be written :—

$$\nabla^4 w = -\lambda\bar{y}\frac{\partial^2 w}{\partial x^2} \quad . \quad . \quad . \quad . \quad (1)$$

λD is then the datum thrust which is just sufficient to maintain the buckled configuration; the configuration for which λD is a minimum will be known as the "critical mode" and the corresponding value of λD as the "critical thrust" for the plate.

If now the plate is covered with a square-mesh net having sufficient intersections to define the distribution of w, we can say that provided equation (1) is satisfied at every point and that in addition λ is a minimum, then the distribution of w is the required critical mode. It should be noted that the absolute magnitude of w is indeterminate so long as the amplitude is sufficiently small for membrane forces to be neglected. The critical thrust can be found from the relation :

$$\lambda = \frac{\Sigma\nabla^4 w}{\Sigma\bar{y}\dfrac{\partial^2 w}{\partial x^2}} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

For the numerical solution these equations are expressed in terms of finite differences. The accuracy of λ will then be determined by the accuracy of the difference equations for the mesh length "a" which is chosen for the relaxation.

As the mesh size was progressively reduced the following values were obtained for case "A."

a	λ	Increase on previous value
$B/4$ ...	249 ...	...
$B/8$ ...	336 ...	87
$B/16$ ...	385 ...	49

Contours of relative displacement for $a=B/8$ and $a=B/16$ are shown in Fig. 2.

It is evident that the finite difference approximations give rise to an appreciable error in λ. As the labour involved in advancing to a finer net would have been prohibitive

Notation

$x\ y\ z$—Rectangular co-ordinates.
E—Modulus of Elasticity (13,200 tons per square inch).
σ—Poisson's ratio (0·28).
h—Web thickness.
B—Web breadth.
D—$\dfrac{Eh^3}{12(1-\sigma^2)}$.
a—Mesh length of relaxation net, expressed either as a fraction of the plate breadth, or in inches.
$\nabla^4 w$—$\dfrac{\partial^4 w}{\partial x^4}+\dfrac{2\partial^4 w}{\partial x^2\partial y^2}+\dfrac{\partial^4 w}{\partial y^4}$.
$u\ v\ w$—Displacements in x, y and z directions due to buckling.
$\bar{y}$—A fraction of $B/2$.
$P_x P_y S$—Edge forces per unit length.
P—Datum edge thrust.
λ—P/D.
$X_x Y_x X_y$—Mid-plate stresses due to buckling.
$P_x P_y P_{xy}$—Extreme fibre stresses due to buckling.
"*Case A*"—Web plate having all its edges clamped against rotation.
"*Case B*"—Web plate having its edges parallel to direction o loading "clamped," and the other two edges "pinned."
B0—Test girder having webs 0·04in thick.
B1—Test girder having webs 0·05in thick.
B2—Test girder having webs 0·06in thick.

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‡ "Relaxation Methods Applied to Engineering Problems VIIIA"; "Problems Relating to Large Transverse Displacements of Thin Elastic Plates," J. R. Green and R. V. Southwell, *Phil. Trans. Royal Soc.*, London. Series C, No. 6, Vol. 1, pages 137–176, 1944.

§ D. M. A. Leggett: "On the Elastic Stability of a Rectangular Plate, When Subjected to a Variable Edge Thrust," *Proc. Camb. Phil. Soc.*, Vol. 31, 1935.

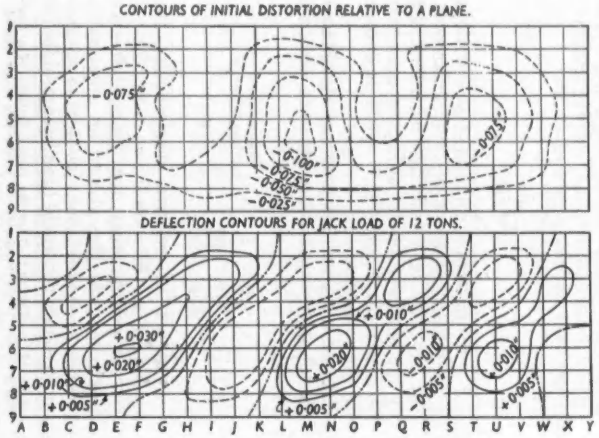


Fig. 9—Web deflections for box girder B0

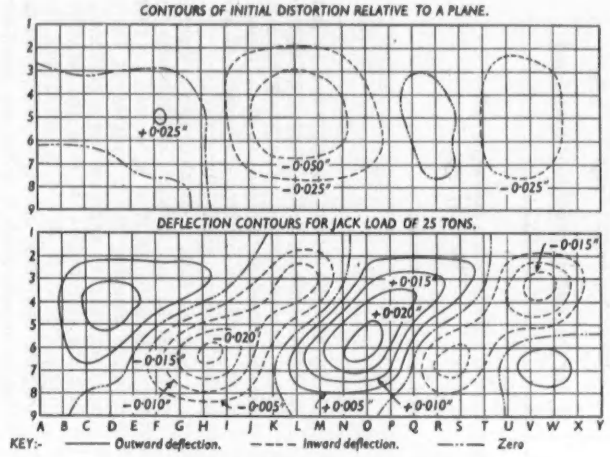

CONTOURS OF INITIAL DISTORTION RELATIVE TO A PLANE.
DEFLECTION CONTOURS FOR JACK LOAD OF 25 TONS.
KEY:- Outward deflection. Inward deflection. Zero

Fig. 10—Web deflections for box girder B1

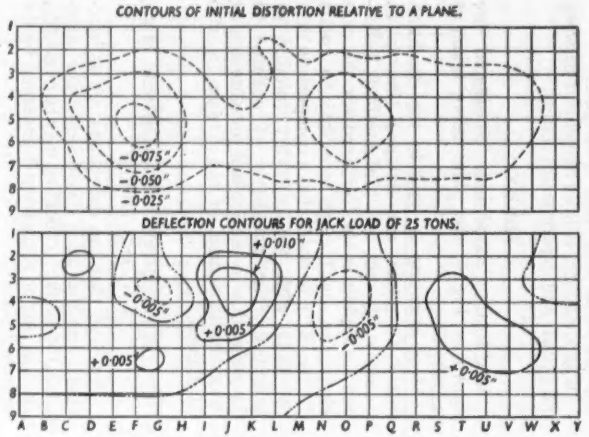


Fig. 11—Web deflections for box girder B2

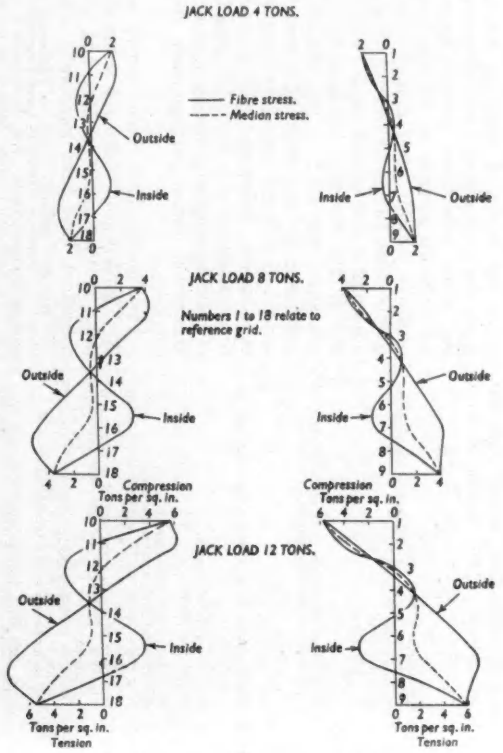


Fig. 12—Stress distribution in webs B0

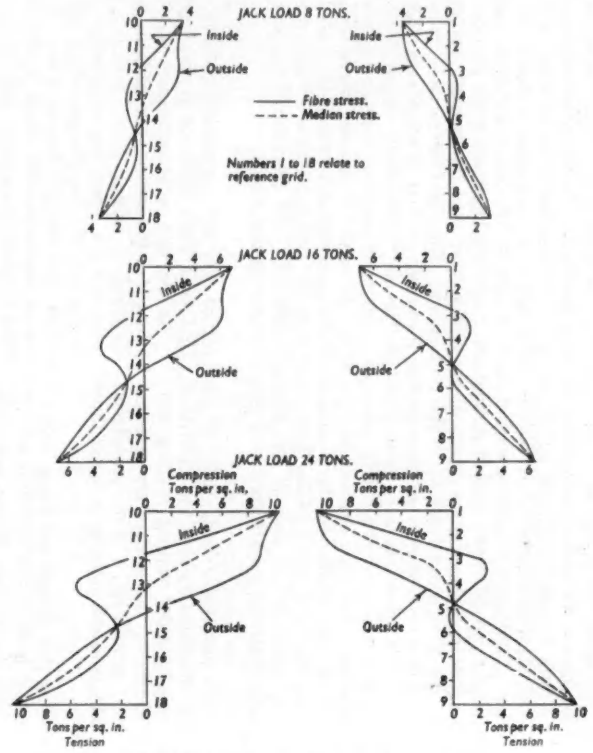


Fig. 13—Stress distribution in webs B1

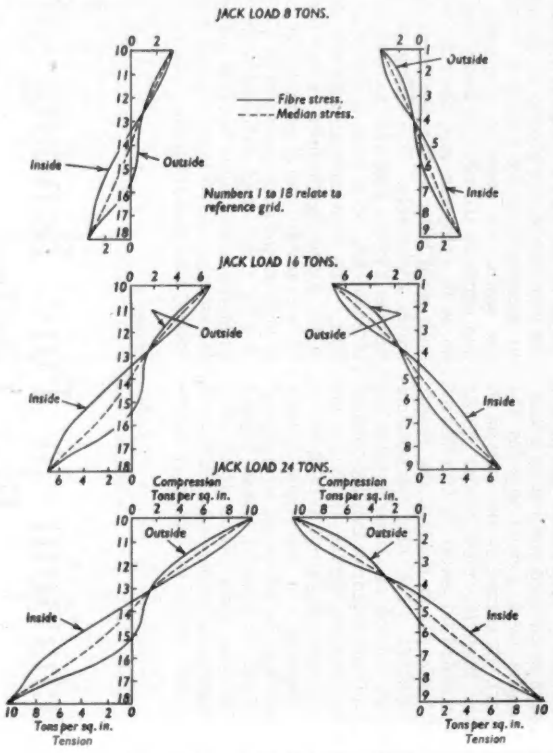


Fig. 14—Stress distribution in webs B2

(for $a=B/16$ there are 360 mesh points), it was decided to carry out a detailed solution of the simpler case "B." The relaxation results could then be compared with Leggett's and a further study could be made of the effect on λ of successive advances to a finer net.

When the loaded ends of the plate are simply supported it is evident that the plate will buckle into similar waves of equal amplitude. Leggett has shown that a plate having a length-breadth ratio of three will have a six half-wave critical mode; accepting this in the first instance, it can be seen that a net having $a=B/4$, $B/8$, $B/16$, ... will suitably describe one quarter-wave. This symmetry can be used in the relaxation, and the number of mesh points is reduced accordingly. Also, the process of relaxation was much more effective than in case "A," where the several waves of varying amplitude gave rise to adjacent regions of residuals of opposite sign which were difficult to liquidate, owing to the low central value of the pattern; an improvement in one region would lead to a worsening in the adjacent

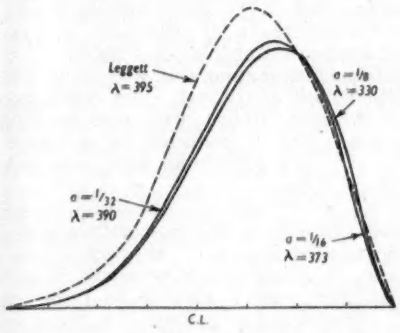


Fig. 15—Case "B" critical mode centre line profile

regions. In case "B," however, it was only necessary to relax until the residuals were of one sign, when a recalculation of λ would lead to a substantial improvement.

After distributions of deflection had been found for $a=B/4$, $B/8$, and $B/16$, it became apparent that the distribution in the x direction conforms exactly to a sine wave, for all values of a. This observation was used to simplify the relaxation for $a=B/32$, and a simple device enabled the distribution to be found by means of a "line-relaxation" on an anti-node. The successive values of λ are :—

a	λ	Increase on previous value
$B/4$ ...	244	...
$B/8$ ...	330	86
$B/16$ ...	373	43
$B/32$ ...	390	17
Leggett	395	5

The relaxation estimate of λ is now only 1·3 per cent below Leggett's analytical value. Profiles on the vertical centre-line are shown in Fig. 15 above, and Leggett's (approximate) configuration is plotted on the same base. Fig. 3 shows contours of deflection for $a=B/32$.

In order to confirm that the six-wave solution does in fact represent the gravest mode, and to find the effect on λ of tuning to a higher or lower mode, five, seven and eight half-wave solutions were derived on a net having $a=B/8$. These solutions were readily obtained by a variation of the device described above. Initial guesses of transverse distribution were based on the six wave solution. Values of λ were :—

Five-wave :	344	Seven-wave :	332
Six-wave :	330	Eight-wave :	344

Evidently λ is not very sensitive to a change in mode.

Finite Deflections

Calculation of Displacements.—When the amplitude of buckling becomes appreciable, the consequent stretching of the plate results in the development of tensile membrane stresses which in turn affect the rate of growth and mode of buckling. A study of the post-buckling behaviour of a plate, then, requires the solution of the "Von Karman" equation, which may be written :—

$$\nabla^4 w=\frac{h}{D}\left[X_x\frac{\partial^2 w}{\partial x^2}+Y_y\frac{\partial^2 w}{\partial y^2}+2X_y\frac{\partial^2 w}{\partial x\partial y}\right]-\lambda\bar{y}\frac{\partial^2 w}{\partial x^2} \quad . . . . . (3)$$

The stresses are given by :—

$$X_x=\frac{E}{1-\sigma^2}\left[\frac{\partial u}{\partial x}+\sigma\frac{\partial v}{\partial y}+\tfrac{1}{2}\left\{\frac{\partial w}{\partial x}\right\}^2+\frac{\sigma}{2}\left\{\frac{\partial w}{\partial y}\right\}^2\right]$$

$$Y_y=\frac{E}{1-\sigma^2}\left[\frac{\partial v}{\partial y}+\sigma\frac{\partial u}{\partial x}+\tfrac{1}{2}\left\{\frac{\partial w}{\partial y}\right\}^2+\frac{\sigma}{2}\left\{\frac{\partial w}{\partial x}\right\}^2\right]$$

$$X_y=\frac{E}{2(1+\sigma)}\left[\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}+\frac{\partial w}{\partial x}\cdot\frac{\partial w}{\partial y}\right] \quad . . (4)$$

So equation (3) may be written in terms of displacements :—

$$\nabla^4 w=\frac{12}{h^3}\left[\frac{\partial^2 w}{\partial x^2}\left\{\frac{\partial u}{\partial x}+\sigma\frac{\partial v}{\partial y}+\tfrac{1}{2}\left(\frac{\partial w}{\partial x}\right)^2+\frac{\sigma}{2}\left(\frac{\partial w}{\partial y}\right)^2\right\}+\frac{\partial^2 w}{\partial y^2}\left\{\frac{\partial v}{\partial y}+\sigma\frac{\partial u}{\partial x}+\tfrac{1}{2}\left(\frac{\partial w}{\partial y}\right)^2+\frac{\sigma}{2}\left(\frac{\partial w}{\partial x}\right)^2\right\}+(1-\sigma)\frac{\partial^2 w}{\partial x\partial y}\left\{\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}+\frac{\partial w}{\partial x}\cdot\frac{\partial w}{\partial y}\right\}\right]-\lambda\bar{y}\cdot\frac{\partial^2 w}{\partial x^2} \quad . . . . . (5)$$

and λ can be found from the expression :—

$$\lambda=\frac{\Sigma 12/h^3\left[\ldots.\right]-\Sigma\nabla^4 w}{\Sigma\bar{y}\dfrac{\partial^2 w}{\partial x^2}} \quad . . (6)$$

Now from the equations of equilibrium,

$$\frac{\partial X_x}{\partial x}+\frac{\partial X_y}{\partial y}=0\,; \qquad \frac{\partial Y_y}{\partial y}+\frac{\partial X_y}{\partial x}=0,$$

and equations (4), we derive the following expressions for u and v :—

For u,

$$2\frac{\partial^2 u}{\partial x^2}+(1-\sigma)\frac{\partial^2 u}{\partial y^2}+(1+\sigma)\frac{\partial^2 v}{\partial x\partial y}+2\frac{\partial w}{\partial x}\cdot\frac{\partial^2 w}{\partial x^2}+(1-\sigma)\frac{\partial w}{\partial x}\cdot\frac{\partial^2 w}{\partial y^2}+(1+\sigma)\frac{\partial w}{\partial y}\cdot\frac{\partial^2 w}{\partial x\partial y}=0 \quad . . . . . (7)$$

and for v,

$$2\frac{\partial^2 v}{\partial y^2}+(1-\sigma)\frac{\partial^2 v}{\partial x^2}+(1+\sigma)\frac{\partial^2 u}{\partial x\partial y}+2\frac{\partial w}{\partial y}\cdot\frac{\partial^2 w}{\partial y^2}+(1-\sigma)\frac{\partial w}{\partial y}\cdot\frac{\partial^2 w}{\partial x^2}+(1+\sigma)\frac{\partial w}{\partial x}\cdot\frac{\partial^2 w}{\partial x\partial y}=0 \quad . . . . . (8)$$

All displacements are those which arise from buckling, and X_x Y_y X_y are the mid-plane stresses which are induced by such displacements. The boundary conditions specified were :—

$$w=\frac{\partial w}{\partial x}=\frac{\partial w}{\partial y}=u=v=0.$$

These conditions were chosen as most nearly representing those of the experiments, where thin webs were welded to relatively thick flanges; they cannot, of course, be rigorously justified, for the assumption $u=0$ infers an infinite value for E in the flanges, whilst the condition $v=0$ implies that the flanges are infinitely stiff. Both these stipulations are manifestly unattainable, but are considered to be better approximations to the actual conditions than other possible assumptions (say, $X_x=Y_y=0$, or $u=\partial v/\partial y=0$), although the second of these two alternatives is also used subsequently for the long boundaries. Equations 5, 6, 7 and 8, together with the specified boundary conditions, enable compatible values of u, v, w, and λ to be found by a process of "iterative relaxation." It should be noted that the displacements u, v and w now assume a definite magnitude in relation to the plate thickness h; for convenience, the numerical value of w at the quarter-point of the centre line was maintained at 1000, as before. After laborious computations involving in addition to 120 relaxation processes, about 180,000 tabulated machine calculations, distributions of u, v and w were obtained for a particular value of λ, the maximum displacement w being equal to about three-quarters of the plate thickness. Contours for w are shown in Fig. 4. A solution for a larger deflection was not attempted. In the early stages of the work various devices were tried with a view to improving the convergence, but none was successful.

Calculation of Stresses.—Having found displacements at all points on the net, the stresses X_x, Y_y and X_y follow from equations (4), whilst surface stresses are given by the equations :—

$$p_x=\pm\frac{Eh}{2(1-\sigma^2)}\left[-\frac{\partial^2 w}{\partial x^2}-\sigma\frac{\partial^2 w}{\partial y^2}\right]+X_x$$

$$p_y=\pm\frac{Eh}{2(1-\sigma^2)}\left[-\frac{\partial^2 w}{\partial y^2}-\sigma\frac{\partial^2 w}{\partial x^2}\right]+Y_y$$

$$p_{xy}=\pm\frac{Eh}{2(1+\sigma)}\cdot\frac{\partial^2 w}{\partial x\partial y}+X_y \quad . . . (9)$$

Stress distributions at typical cross-sections are shown in Fig. 5. It is seen that the stress Y_y is negative at the upper boundary, indicating compression; that this condition is inconsistent with the stresses obtaining elsewhere may be deduced either from our conception of "membrane stress," or by applying the equations of equilibrium at points adjacent to the boundary. This discrepancy may probably be explained by the fact that the net used is too coarse to describe adequately the erratic distributions of u and v.

Vertical Collapse of Webs

When a box beam is subjected to flexure, the curvature of the flange causes a vertical pressure to act on the webs; if the webs are very deep and thin, this pressure may be sufficient to cause them to fail as struts. This possibility will now be investigated by an approximate method.

It is assumed that the beam is long in comparison with its depth, and that the flanges have a negligible bending rigidity about their own axes. Then, referring to Fig. 6, the vertical component of the thrust H per unit width of flange, is resisted entirely by the uniform vertical thrust p_w in the webs.

For equilibrium,

$$p_w=\frac{8\Delta H}{L^2}.$$

By the simple theory of bending,

$$H=\tfrac{1}{2}EtcB$$

where c is the curvature,

and

$$\Delta=\frac{cL^2}{8} \text{ approximately,}$$

so substituting for H and Δ, we have

$$p_w=\tfrac{1}{2}Etc^2B \quad . . . . . (10)$$

This equation was derived by Brazier.‖

‖"On the Flexure of Thin Cylindrical Shells and Other 'Thin' Sections," L. G. Brazier, *Proc. Royal Soc.*, London. Series A, Vol. 116, 1927.

If the flange has an initial eccentricity δ, then

$$\Delta=\frac{cL^2}{8}+\delta$$

whence

$$p_w=\tfrac{1}{2}Etc^3B\left(1+\frac{8\delta}{cL^2}\right).$$

Now considering the thinnest webs of the boxes tested, for which h=0·040in, t=0·23in, δ=0·016in, we find that for a flange stress of 10 tons per square inch, p_w is about one-tenth of that which would be required to cause Eulerian strut buckling in the webs. In view of the conservative assumptions made, this type of instability is evidently unlikely to occur in the girders tested, and is not considered further in the present article.

Experimental Procedure and Results

Tests were carried out on three welded box girders, and the centre section, which was 24in long and 8in square, was subjected to pure bending. The web thicknesses were

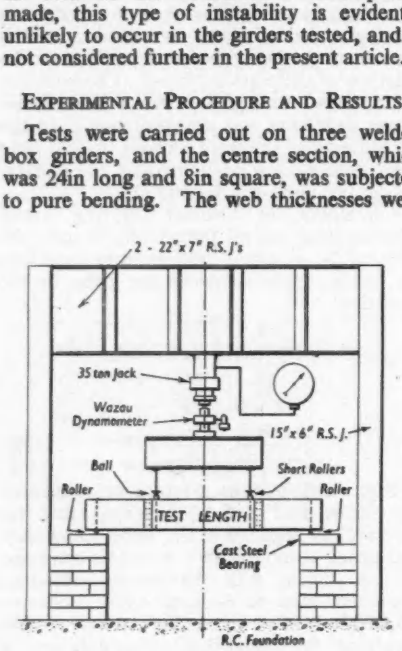


Fig. 16—Loading arrangement for box girders with thin webs

0·04in, 0·05in and 0·06in ; it was hoped to include tests on a box having thinner webs, but the fabrication proved too difficult. Details of the boxes are shown in Fig. 7, and the reference grid for deflection and stress measurements in Fig. 8.

Load was applied to the girders by a hydraulic jack through a Wazau mercury dynamometer and a distribution girder (Fig. 16). Three-point loading on the centre section bulkheads was provided by a ball and two short rollers, whilst the end reactions were rollers on level cast steel bearings ; in this way twisting and horizontal restraint were minimised.

For girders *B*1 and *B*2 loads were applied in increments up to 25 tons. In the case of girder *B*0, however, one web exhibited a sudden and noisy change of mode at a load of about 13 tons, and although this caused no apparent damage loads were thereafter restricted to 12 tons.

Initial distortions in the webs were measured by a dial gauge mounted on a scribing block, the box being supported on a plane table by three points at the bulkheads. The configuration of each web was then related to a mean plane passing through its edges. Deflections under load were measured by dials reading to 1/10,000in ; they were fixed to duralumin angles attached to two rectangular frames which were supported from the centre section bulkheads by pointed set-screws mid-way between the flanges.

Web deflections were measured at 1in centres for several load increments. Deflections which were measured along the centre lines and edges of the flanges indicated that they were deflecting linearly and in accordance with simple beam theory.

Inside and outside surface strains around the centre section of each box were measured by Tinsley 90 ohm electrical resistance strain gauges in conjunction with a forty-eight-channel modified Kelvin bridge.

Deflection contours and stress distributions for the webs of the three boxes are shown in Figs. 9 to 14 on page 254.

In order to test the validity of a part of the theoretical treatment, and to investigate the possibility of deducing stresses from measured deflections, u and v distributions for one web of girder *B*0 were found by relaxation from equations (7) and (8), using the measured values of w. The assumed boundary conditions for the short edges were as for the theoretical treatment ($u=v=\partial w/\partial x=0$), whilst two different assumptions were made for the conditions at the long edges ($u=v=\partial w/\partial y=0$ and $u=\partial v/\partial y=\partial w/\partial y=0$). The alternative distributions of u and v so found were used to calculate longitudinal stresses on the transverse centre-line and the distribution for the first condition is shown graphically in Fig. 17. The stresses differ little for the alternative edge conditions.

Discussion of Results

The relaxation method as applied to plate buckling problems may be criticised on the ground that the labour involved is very considerable, and that the solution obtained is limited to "families" of plates having the same length-breadth ratio. Against this it should be said that the method is normally used only where the problem is intractable by orthodox methods, and that the solution, being in terms of displacements, is very complete. Some experience of the technique is required before progress can be made with a biharmonic solution having nodal lines, and considerably more experience is needed before a "finite deflection" solution of this sort can be obtained.

It has been demonstrated in the test case "B" that the analytical value for λ is not approached (for our particular case of rapidly varying edge thrust) until a very fine net is used ; λ is about 16 per cent low for a $a=B/8$. We must, therefore, expect a comparable error for the finite deflection case "A," and in this instance an advance to a finer net is scarcely feasible.

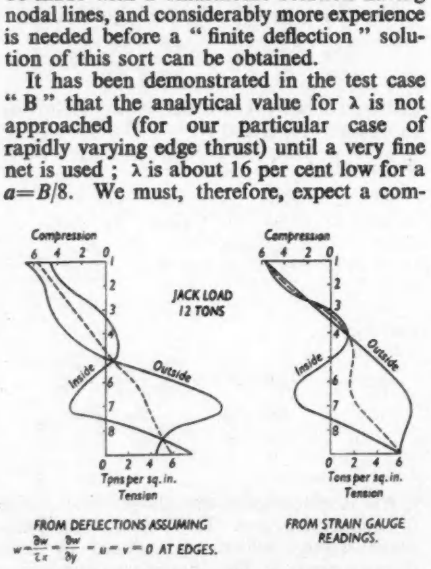


Fig. 17—Stress distribution from measured deflections box B0

An interesting feature of case "B" is the early emergence of the longitudinal sine wave distribution ; the simplification of the process which resulted from this is an example of the way in which the flexibility of the relaxation method may be turned to advantage for a particular problem.

If we accept that the estimates of the critical thrust when $a=B/16$ for cases "A" and "B" bear the same relation as the final values, we can say that for "A" :—

$$\lambda_{crit}=\frac{385}{373}\times 395=407 \text{ approximately.}$$

Then the critical edge stresses for the webs of the boxes tested are found to be :—

*B*0 ... 12 tons per square inch
*B*1 ... 19 tons per square inch.
*B*2 ... 27 tons per square inch.

Thus, it was not possible to reach the theoretical critical stress for any of the girders tested. However, lateral deflections occurred which were of the same order as the plate thickness, and surface stresses very different from the mean were measured. Critical behaviour can only be expected when great care is taken to ensure that the plating is initially flat. Owing to the difficulty of welding together plates of different thicknesses, the initial distortions of the boxes tested were large in proportion to the other dimensions, and this certainly accounts to some extent for the varied nature of the buckling patterns. The inclination of the buckles can be explained by the fact that under load an initial buckle will be accentuated in the upper half of the web, and diminished in the lower half. It is seen, contrary to reasonable expectations, that the maximum deflections may well occur in the tension half of the web. The development of membrane stress occurs more rapidly in practice than is predicted by the present theory ; this is probably due to the initial lack of flatness.

Fig. 17 shows a comparison between measured stresses and those calculated from measured deflections ; although the similarity in distribution is apparent, it seems that even were it possible to predict the distribution and magnitude of w, the stresses calculated would not closely represent the actual stresses. One reason for this discrepancy is apparent if we examine the distribution of u and v ; the variation of these displacements is so erratic and abrupt that, on the coarse relaxation net used, difference equations cannot reasonably be expected to approximate closely to the derivatives ; w, however, varies more regularly, and calculated bending stresses are in general of the same order as those measured.

Conclusions

It is difficult to draw general conclusions from experimental results which are largely influenced by conditions peculiar to the few specimens examined. On the other hand, we may probably assume that the initial deformations of the girders tested were larger than may reasonably be expected in practice, and therefore any design rules which may be formulated in the light of the results will probably err on the side of safety. The following observations are considered to have some generality.

(1) The relaxation method can be applied without great difficulty to the solution of idealised "infinitesimal deflection" plate buckling problems, even where the distribution of edge thrusts and the nature of the boundary conditions are such as to present considerable obstacles to an orthodox solution. In certain simple cases the relaxation process may be greatly shortened.

(2) Clamping of the loaded edges of the plate considered has little effect on the critical thrust.

(3) The theoretical solutions obtained have not been found to represent quantitatively the deflections or stresses measured experimentally.

(4) Within the limitations imposed by the finite difference equations, and at the expense

of laborious computation, the method may be applied to "finite deflection" problems of the type described. It may be that it would be more profitable to consider an infinitely long plate and to make certain assumptions concerning the longitudinal distribution of deflection and stress. Suitable assumptions may be :—

(*a*) That the longitudinal distribution of w continues to be a sine wave after buckling.

(*b*) That the membrane stress X_x does not vary in the x direction, and that $Y_y=0$. It would follow that $X_y=0$. Assumptions of this type would probably enable the transverse distribution of deflection and stress to be found by means of a line relaxation. An advance to a smaller mesh length would then be feasible. The wave length would be established by treating the mesh length in the x direction as a variable.

(5) The conception of a critical thrust has little significance in practical cases where an initially flat plate cannot be guaranteed. Where structural components of welded thin steel plating are concerned the designer must contemplate buckling for the smallest loads ; he should then decide :—

(*a*) Whether the consequent reduction in carrying capacity of the plate will materially affect the structure as a whole.

(*b*) Whether surface stresses will exceed the yield stress, and if so, whether in view of repetitive or reversible loading which might occur, this yielding may be permitted.

In the case of web design, it seems that provided the breadth/thickness ratio is not greater than about 200, the buckling of the web due to pure bending, although liable to occur, need not concern the designer ; for the contribution of the web to the total strength of the girder is not appreciably affected, and the surface stresses due to buckling are unlikely to exceed the flange stresses.

ACKNOWLEDGMENT

The work described was done in the department of civil engineering, Imperial College of Science and Technology. The author is indebted to the British Shipbuilding Research Association, who provided the test specimens.

Major Development Proposals in the Canadian North-West

WE have received some preliminary details of proposals which have been put forward for a major industrial development scheme in the North-West of Canada. The scheme is based upon the hydro-electric development of the headwaters of the Yukon River, near its source at Atlin lake, in British Columbia which, with various surrounding catchments, will eventually yield 4,300,000 h.p., it is stated. The natural advantages of the area and construction in stages will enable this power to be developed at a low cost to form the basis of a metallurgical industry, which it is planned to create on the left bank of the Taku River, just inside the Canadian boundary with Alaska. The principal aims are : to refine nickel-cobalt ores and concentrates brought from New Caledonia, the Philippines and other Pacific islands ; to smelt Pacific coast iron ores and concentrates for the production of pig iron and steel ; to produce ferro-manganese and silico-manganese from South-West African ores ; and to treat zinc concentrates, and concentrates of other base metals which are available in neighbouring parts of Canada.

The companies responsible for this scheme are North-West Power Industries, Ltd. (a subsidiary of Quebec Metallurgical Industries, Ltd.), and Frobisher, Ltd. (a subsidiary of Ventures, Ltd.). It is stated that, assuming the necessary licences are obtained from the Governments of Canada and British Columbia before the end of this year, work will begin next year. If this programme is adhered to, it is envisaged that hydro-electric power to the extent of 880,000 h.p. (about 660MW) will be available by 1962, in conjunction with the daily treatment of 5500 tons of nickel-cobalt ore and the daily production of 550 tons of iron and steel and 450 tons of manganese alloys. An expenditure of 52 million dollars on metallurgical plant and 213 million dollars on hydro-electric power would be necessary to complete the 1962 stage of the programme.

The basic layout of the hydro-electric developments envisaged in these proposals bear some resemblance to the Nechako-Kemano scheme—the large development further south in British Columbia, the first stage of which was opened recently—in that natural storage is provided by lakes at the head of a river system and is exploited by a diversion through the watershed into a neighbouring catchment at a much lower level. In this case the lakes, of which the principal one is lake Atlin, are in the upper part of the course of the Yukon River, which flows to the north, and then to the east, reaching the sea on the eastern coast of Alaska. The proposed diversion is thus southwards into the Taku River, which flows from east to west into the Pacific Ocean, just south of Atlin lake. A dam will be built on the Yukon, near Whitehorse, north of the lakes, and water will be diverted from the southern tip of lake Atlin into the Taku River catchment. This diversion involves a tunnel a mile long, connecting Atlin lake with Sloko lake, and then a tunnel almost 10 miles in length to the first power station of the scheme, situated on the Nakonate River, a tributary of the Taku. Lake Atlin is 2192ft above sea level, and a head of 1092ft will be available for this power station, which will provide an estimated maximum output of 2,800,000 h.p. A second stage of development utilising the head available below this power station down to the Taku River is envisaged, and a third stage still further downstream is under investigation.

Augmentation of the catchment supplying lake Atlin is proposed by a second dam about 40 miles from Whitehorse on the Teslin River, with diversion works to the Yukon River, and also, at a later stage, by diverting the water from the next catchment on the western side—that of the upper Alsek River—into the Yukon catchment at the Takhini River. The third main dam of the scheme will be just below the confluence of the Yukon and Salmon rivers. The total catchment area involved extends over 200 miles in the north-south direction (from Atlin lake to the mouth of the Big Salmon River) and 300 miles in the east-west direction (from Rancheria to Burwash). The hydro-electric consultants for the scheme are Dr. T. H. Hogg and James M. Wardle.

At the proposed site of the industrial plant on the Taku River, power from the hydro-electric stations would be brought by transmission lines about 45 miles long, and raw ores and concentrates would be brought up the river by barge from deep water, a distance of 20 miles. Alternative land transport from a deep water terminal in Alaska is possible.

Prototype Light Jet Fighter Aircraft

LAST week the first flight was made with the "Midge," the prototype of the "Gnat," light jet fighter, developed by Folland Aircraft, Ltd., of Hamble, near Southampton, and designed by Mr. W. E. W. Petter. The tests were carried out at Boscombe Down, where the "Midge" was first given preliminary tests, including engine runs, and afterwards taxying trials were followed by a fast run down the runway, a "hop" and a landing. After refuelling initial flying tests started in earnest, with slow rolls, tight turns, &c.

The experimental "Midge," to be seen in the illustration on this page, is externally almost identical with the "Gnat," the main difference between the two types being in the engines fitted. The "Midge" has the Armstrong Siddeley "Viper" turbojet of 1640 lb thrust, whilst the "Gnat" will have a Bristol "Orpheus," a new engine now being developed, which is stated to give three times the thrust of the "Viper." Construction of the first "Gnat" has just started and some months will elapse before it is finished.

The "Gnat," with a weight no greater than that of an early version of the "Spitfire" piston-engined fighter, will, it is stated, have an extremely high subsonic speed and will reach supersonic speed in a dive. In spite of its low weight and small size—it has a span of only 20ft 8in—the new machine will have a very complete flying, navigational and armament equipment, a destructive fire power, a good endurance, and will be suitable for use either as an interceptor or as a fighter bomber for use with tactical air forces. As a fighter bomber it can carry high-explosive or napalm bombs, or batteries of 3in air-to-ground rockets.

The Folland "Midge," prototype of the "Gnat," light jet fighter. The "Midge" has an Armstrong Siddeley "Viper" engine but the "Gnat" will have the more powerful Bristol "Orpheus"

The makers state that, fully equipped, the "Gnat" will cost between one-third and one-quarter the price of a standard fighter, and it is claimed that no fewer than five "Gnat" airframes can be built in the man-hours required for one standard fighter airframe. A further point in the design of the new machine is its mobility. With only the wings removed, two of these aircraft can be transported in a single Blackburn "Beverley" air freighter, together with their pilots and ground crews. The wings are in one piece and stack quite easily in the "Beverley's" capacious hold.

We understand that when the "Midge" makes its debut at Farnborough this year, it will have the appearance, but not the performance, of the "Gnat." Nevertheless, it is stated, when the programme flight trials have been completed in a month or two's time, it will be capable of flying at more than 600 m.p.h.

COLOMBO PLAN MEETING.—The Marquis of Reading, Minister of State, Foreign Office, will lead the United Kingdom delegation to the forthcoming meeting of the Colombo Plan Consultative Committee in October. This year, at the invitation of the Canadian Government, the meeting will be held in Ottawa.

MANUFACTURE AND TESTING OF WATER-WHEEL ALTERNATORS AT RUGBY

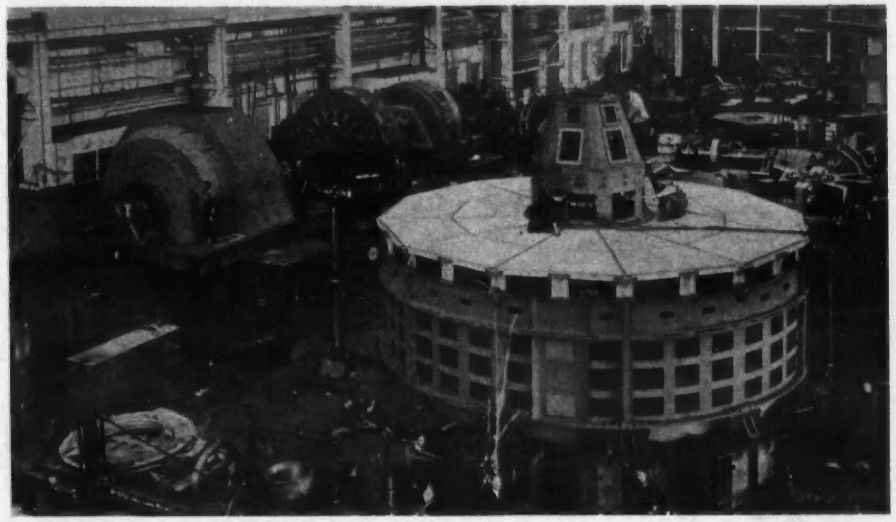


Fig. 1—44,444kVA, 136 r.p.m., vertical water-wheel alternator for Roxburgh power station, New Zealand. On the left is a 35,294kVA, 375 r.p.m., horizontal water-wheel alternator for Finlarig power station, North of Scotland Hydro-Electric Board

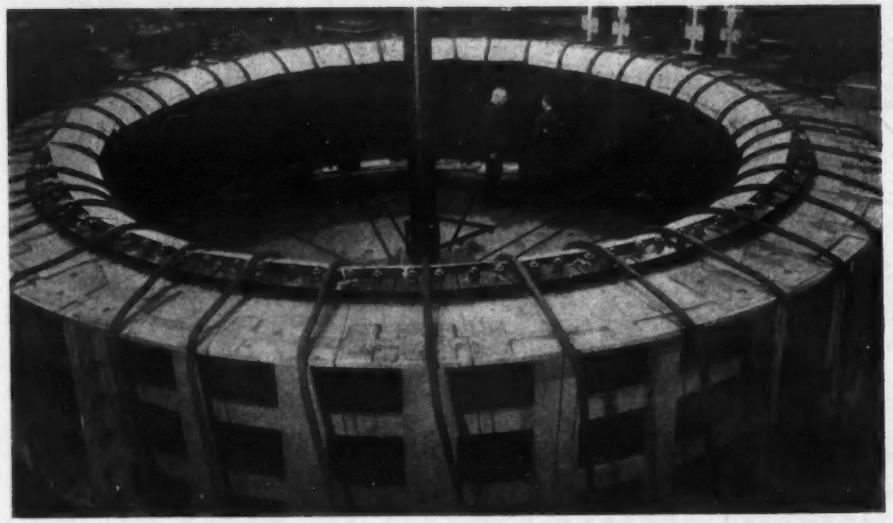


Fig. 2—Unwound stator frame of 44,444kVA, 136 r.p.m., vertical water-wheel alternator for Roxburgh power station undergoing ring flux test at the Rugby works

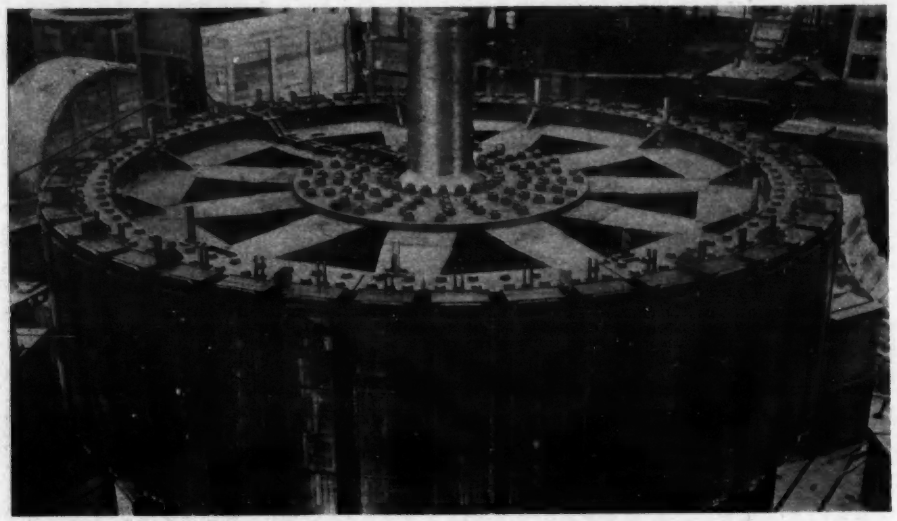


Fig. 3—Rotor of 44,444kVA vertical water-wheel alternator. The fabricated field coils and the absence of damper winding connections between the poles may be noted

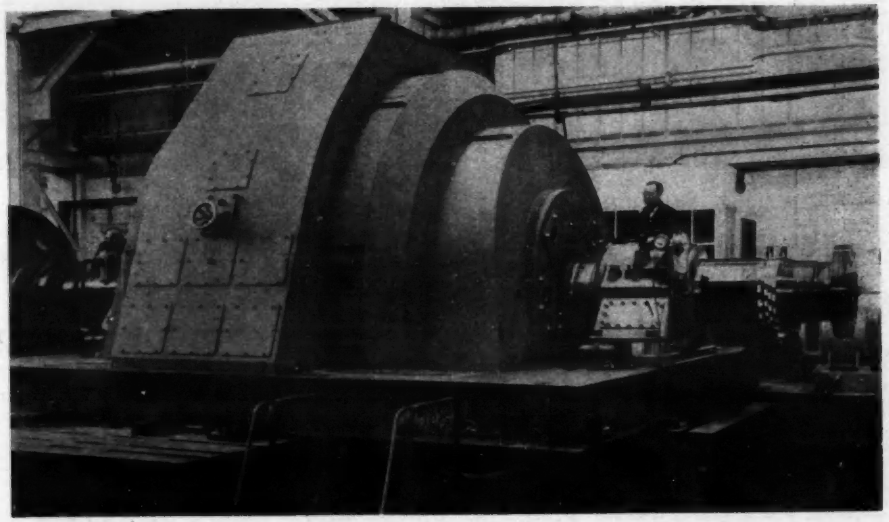


Fig. 4—35,294kVA, 136 r.p.m., vertical water-wheel alternator for Finlarig, erected for works testing. The main exciter forms part of the set, being mounted inside the alternator enclosure to the left of the main bearing

Manufacture of Large Water-Wheel Alternators at Rugby

Since the war there has been a substantial expansion in workshop capacity for building and testing heavy generating and transforming plant at the Rugby Works of the British Thomson-Houston Company, Ltd. The new installations include a heavy plant shop which has facilities for the manufacture and testing, in one building, of large transformers and generators; there is also a balancing and overspeed test house for rotors. Here we give some impressions gained from a recent visit to these works, when we were shown the new test plant and two large water-wheel alternators assembled for works tests.

TWO large water-wheel alternators erected for shop tests provided the main reason for a visit, on August 11th, to the Rugby works of the British Thomson-Houston Company, Ltd. The visit also gave us the opportunity of seeing recent extensions to the heavy plant manufacturing capacity and some interesting additions to the company's testing facilities, including a new balancing and overspeed test house.

One of the reasons for providing these improved facilities is to reduce lost time, particularly in preparing plant for test, and thereby to accelerate progress through the works, without restricting the time needed by the design department for "research and development" testing. For, as Mr. W. S. Steel (director, plant and apparatus sales) emphasised during the visit, his company as a manufacturer (*inter alia*) of heavy power plant is very much alive to the importance of two items in the capital account: one is the amount "tied up" in work going through the shops; the other is the amount represented by the workshops and plant, including the productive and testing installations. The expenditure on these installations is justified to the extent that it reduces transit time and accelerates production. But, as Mr. Steel pointed out, whereas producers of consumer goods may be planning perhaps two or three years ahead, the manufacturers of heavy generating plant have to look ten or fifteen years ahead in planning their extensions, making allowances as far as possible, for trade fluctuations. Since the war expenditure of this kind at the Rugby works has, we learned, totalled more than £1,500,000, including about £400,000 on test equipment alone.

One of the main items in this programme of expansion is a new heavy plant shop equipped for the manufacture and handling of large turbo-alternators and transformers with the necessary facilities in one building for machining, core building, winding, storing erection and testing. In the accompanying view of this shop (Fig. 1) two large water-wheel alternators can be seen erected for works tests: on the right is the first of four 44,444kVA, 136 r.p.m., vertical-shaft machines for Roxburgh power station of the State Hydro-Electric Department of New Zealand; on the left is a 35,294kVA, 375 r.p.m., horizontal-shaft machine for Finlarig power station of the North of Scotland Hydro-Electric Board.

In passing, it may be remarked that the coincidence of two large water-wheel alternators assembled for works testing is unusual in generating plant manufacture to-day, when the usual practice is to avoid delay by erecting the machines for the first time on site. The alternators themselves are not without interest, and some of the noteworthy points are brought out in the following brief description of the machines and of the power stations in which they will be installed.

Roxburgh Power Station

Roxburgh power station is situated about 100 miles inland from Dunedin and 6 miles from the old gold-mining town from which it takes its name. Ultimately, it will have an installed capacity of 320MW and will be the largest generating station in New Zealand, with an output of nearly half the present installed capacity in that country. It is being built to use the waters of the Clutha, the largest river in New Zealand, which has its source in the Southern Alps, and flows 210 miles almost due south across Central Otago. The existence of gold, albeit in unworkable quantities, is responsible for an unusual clause in the civil engineering contract, to the effect that any gold struck during the excavations for the dam belongs to the Government of New Zealand. A mass concrete gravity dam is being built to raise the level of the river behind it by 150ft, forming a lake about 18 miles long. The power station, which will extend partly across the gorge at the base of the dam, will eventually contain eight generating sets, each rated 44,444kVA, but so far only four of the sets have been ordered. Generation will be at 11kV and the output will be stepped up to 220kV for transmission.

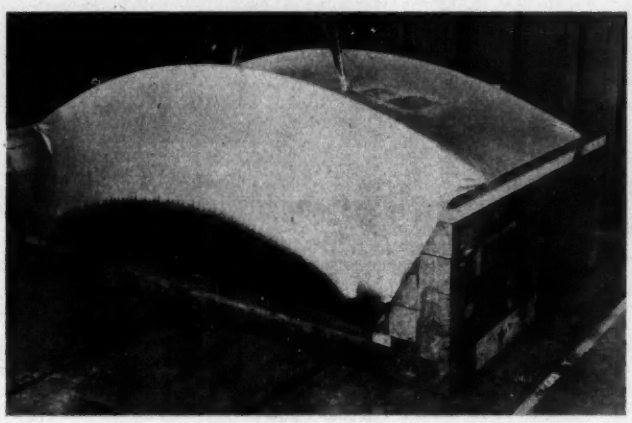


Fig. 5—A section of the stator frame of a 44,444kVA alternator, packed in a protective cocoon for shipment to Roxburgh power station, New Zealand

Each of the sets now being supplied will consist of a B.T.H. vertical water-wheel alternator driven by a Francis turbine made by the Dominion Engineering Company, Montreal. To ensure that the alternators comply with the contract guarantees one machine has been fully assembled in the factory and a series of tests carried out. The remaining machines will be checked for mechanical accuracy, and subjected to such electrical tests as are practicable, including a ring flux test on the stator prior to winding (Fig. 2), to check that the core losses are comparable with those measured on the assembled machine.

After test, all parts that are likely to be stored for some time prior to erection on site are cocooned to prevent deterioration. Stator sections, for example, will be cocooned as shown in Fig. 5, the necessary slings for handling being sealed at the points where they enter the skin. Silica gel is placed inside the cocoon to keep the enclosed air dry, and any leakage can be detected by observing the colour of the silica gel through an inspection window, which can be seen in our illustration.

Each alternator is 29ft in diameter and weighs 330 tons. When erected on site, only the exciter will be above the main floor of the station. Passages are formed in the concrete foundations to give a closed circuit through air/water heat exchangers for the alternator cooling air. The exciters are self-cooled. As the alternators are low-speed machines, their rotors are of laminated rim construction. On the shaft are two forged flanges, to which are bolted heavy steel discs. Eleven radial arms, slotted at their outer ends, are bolted between the discs to form a spider. Around the spider is a laminated rim, built up from ¼in thick steel segments, the laminations being held firmly together by close-fitting bolts. The complete rim is held to the spider by taper keys in the slots at the outer ends of the spider arms, and the poles are keyed to dovetails in the outer periphery of the rim. Both sets of keys can be seen in Fig. 3; the protruding portion of the keys will be removed during final erection of the set on site.

The pole bodies consist of steel laminations, consolidated under hydraulic pressure and held between heavy forged endpieces by rivets passing from end to end of the pole. The rotor field winding is fabricated from hard-drawn copper; each turn of the winding is in the form of a rectangle built up of four strips, the jig-saw joints at the corners being silver soldered. In the pole faces is a heavy damping winding, consisting of copper bars brazed at the ends to copper plates embedded in the pole body. This construction gives effective damping on the quadrature axis without the necessity for pole-to-pole connectors, as can be seen from Fig. 3.

The thrust bearing, mounted in the bottom bracket, is of the Michell segmental-pad type. It is designed to carry a load of 375 tons, comprising the weights of the alternator rotor and turbine runner plus the hydraulic thrust. Guide bearings, also of the Michell type, are mounted in both bottom and top brackets. Brakes, which can also be used as jacks to lift the rotor off the thrust bearing, operate against a ring of heavy polished steel segments mounted below the rotor rim. To avoid distortion due to the heat generated during braking, each segment is held loosely at the edges by clamps and is located and driven by a single dowel.

Solidly coupled to the top of the alternator shaft are the armatures of the main and pilot exciters and the permanent-magnet rotor of the governor generator; the latter provides a three-phase supply for the synchronous motor which drives the pendulum of the turbine governor.

Finlarig Power Station

Finlarig power station, at the western end of Loch Tay, is the power station of the Lawers scheme, of the North of Scotland Hydro-Electric Board. It will operate under a gross head of 1348ft, the highest head so far of any of the Board's projects. Lochan na Lairige, a small loch lying 1620ft above sea level on the high pass between Loch Tay and Glen Lyon in Perthshire, will be greatly enlarged when the dam being built at the southern end is completed. The dam will be 1250ft long, 130ft high, and will raise the level of the loch 90ft. Aqueducts have been constructed to divert the headwaters of the hill streams on Ben Lawers (3934ft) and the hill streams on adjacent peaks, thus enlarging the catchment area of the loch. A tunnel approximately 2 miles long has been driven through the hillside to carry the water to a surge shaft and valve house from which it descends to the power station through a high-pressure steel pipeline.

The 30,000kW water-wheel alternator will be the largest horizontal hydro-electric set installed in this country. The alternator is driven by a twin-jet, double-overhung Pelton turbine, which is being built in Scotland to the designs of Boving and Co., Ltd., London. There are two turbine runners, one mounted at each end of the alternator shaft. Each runner weighs approximately 5 tons, and consists of a forged steel disc to which are bolted eighteen buckets of cast stainless steel. The nozzles, of which there are two for each runner, are controlled by needle valves. The turbine has an output of

42,000 h.p. when running at 375 r.p.m. under a net head of 1250ft and passes about 10 tons of water per second.

The alternator has a continuous maximum rating of 35,294kVA, 11kV, three-phase, 50 c/s, 0·85 lagging power factor, and is designed to withstand the stresses which occur when rotating at the runaway speed of the turbine, in this case 705 r.p.m. Its stator frame is fabricated and, to comply with transport limitations, is in two parts, being split on the horizontal diameter. Dovetail key bars welded inside the frame support the stator core which consists of segmental steel laminations insulated on both sides and clamped between steel segmental flanges. The stator core slots carry a double-layer Roebel bar winding, the transposed conductors reducing the losses in the winding to a minimum. The main insulation on the slot portion of the bar is micafolium, and on the end windings mica tape reinforced mechanically with glass tape. The whole stator, fully wound, weighs 58 tons.

The rotor is a shaft, about 30ft long, on which are shrunk and keyed a number of thick steel plates. Dovetail slots are machined in the rotor body to carry the poles, there being corresponding projections on the poles. Taper keys are driven in from both ends to pull the poles hard down on to the rotor body. The field coils are fabricated from copper strip, the main insulation being " Micanite " and the inter-turn insulation asbestos. A heavy damping winding of copper bars is embedded in the pole faces. As the complete rotor weighs 127 tons all sixteen poles and four of the rotor plates have to be removed to bring the weight down to the permissible limit of 77 tons for transport to the site. The alternator bearings are of the Michell type and are fed with cool, filtered oil from an external lubricating system.

Cooling of the alternators is by a closed-circuit system, hot air being discharged at the bottom of the stator through two air/water heat exchangers in the machine pit. The cooled air is then forced into the alternator at each end by the aerofoil fans on the rotor.

To reduce the overall length of the set, with the object of keeping down excavation costs, the main exciter is located between the stator and the main bearing at the end opposite the sliprings, the armature being carried on the main shaft. Hinged covers with circular inspection windows, four of which can be seen in Fig. 4, give access to the exciter commutator and brushgear. The pilot exciter and governor generator are mounted on a common base plate and are flexibly coupled to one Pelton runner. The governor generator provides a three-phase, 50 c/s supply for the governor pendulum motor.

The B.T.H. control equipment enables the set to be started up automatically, by push button either in the power station itself or in the remote control centre at Killin. It is possible to synchronise the machine remotely and to adjust the load and voltage as may be necessary. Alarm indications are relayed back to the control centre, while more serious faults shut the machine down automatically.

Test Plant for Large Machines

Test plant forms an important part of the post-war extensions to the company's Rugby works. The power demands for testing large machines or transformers are increasingly heavy despite the fact that it is not practicable either to supply the driving power or to absorb the output for a full-load test, except when two similar equipments can be tested " back-to-back." Even to circulate full-load current in the short-circuited windings of a transformer requires a supply of about a fifth of the rated kilovolt-amperes, and a greater capacity is needed for heat runs. The same applies to large a.c. machines, for which, indeed, similar supplies are necessary. The company therefore decided to install a central test generating plant of substantial capacity, both alternating current and direct current, with provision for extension and with facilities for making the output available at various places in factories besides the new heavy plant factory, where the test plant is installed.

For direct current supplies two main d.c. generators are provided ; each is rated at 700V, 2400A at 1500 r.p.m., and is driven by 2000kW a.c. synchronous motors. Their output, and that of a number of smaller auxiliary sets, is used chiefly for testing large d.c. motors and alternators driven from test plant motors, in the heavy plant factory. It is also used, however, for supplying the driving motor of the new overspeed test described below. Both generators can be used singly, or connected in series, or in parallel.

The a.c. generating plant was required to provide simultaneous availability in diverse places and to supply occasional large demands in any one spot. To meet these conflicting requirements the estimated capacity was subdivided : alternators of 20MVA, 5MVA and 1MVA were first installed, each driven by a synchronous motor ; a further 5MVA alternator is being installed and provision has been made for one of 10MVA. All the alternators generate at 12kV and have similar characteristics so that, while they are normally used independently, they can be connected in parallel. By using the motor of one of the d.c. generators as a synchronous condenser it has already been possible to produce an output of 28,000kVA for testing the first 120MVA, 275/132kV transformers for the B.E.A.

This parallel operation of test sets depends on two conditions : first, the electrical " line-up " between motor and alternator has to be correct in each case, to provide for satisfactory load sharing ; secondly, the excitation system has to be such that the alternator voltage control is the same, irrespective either of the number in parallel, or the distance of the control point. This is achieved by the use of auxiliary " Amplidyne " exciters, whose control fields are placed in series when their parent alternators are connected in parallel.

By a simple and positive switching arrangement this varied output up to 28,000kVA can be supplied, via 11kV cables, to five points in the heavy plant factory, in the generator factory, in the turbine factory, and in the motor compressor test house, which is a third of a mile away. At each of these centres there is full control of alternator voltage, switching and protection, or, if the two d.c. generators are used as a Ward-Leonard system (for which provision is made), of frequency. Interlocking for safety and fault protection has been provided on an extensive scale. Any combination of alternator outputs can be made available at any test station by a simple and positive switching operation at a central control room (Fig. 6), where the test staff has overriding control of the output of the plant, the condition of which is shown on a miniature control board.

An interesting point about the motor alternator sets in the machine room is the use of a separate closed-circuit ventilating system, with water coolers for each machine (Fig. 7). The bearings are also water cooled. With these arrangements heat dissipation from the machines, in the limited space of the plant room (Fig. 7), presents no problems. At the same time, the noise emission is greatly reduced—an amenity which is specially desirable when transformers are being tested in the adjoining main shop.

To simplify the procedure for rapid starting of the machines one of the a.c. sets and one of the d.c. sets is provided with pony motor starting. All the other sets are started on variable voltage, usually from the a.c. set, through the medium of a starting busbar and transformers of suitable ratio, before being synchronised on to the main 12kV machine busbar. The whole operation of starting any machine, synchronising and paralleling is effected very simply from the central control board (Fig. 6), which is equipped with the necessary remote control switches, regulators, instruments and mimic diagram with signal lamps.

In a gallery overlooking the test area there are a number of test control stations, with provision for wiring the measuring instruments to transformers in the test area. A single regulator handwheel on a control panel allows for variation of the test voltage which, as explained above, is derived from the machine room (Fig. 7) via the control room (Fig. 6). The panel on the right of Fig. 6 embodies a mimic diagram with signal lamps to indicate the distribution of the available voltage sources to the various points where these supplies can be made available.

Specially designed current and voltage transformers are available to enable measurements at low power factors to be made without correc-

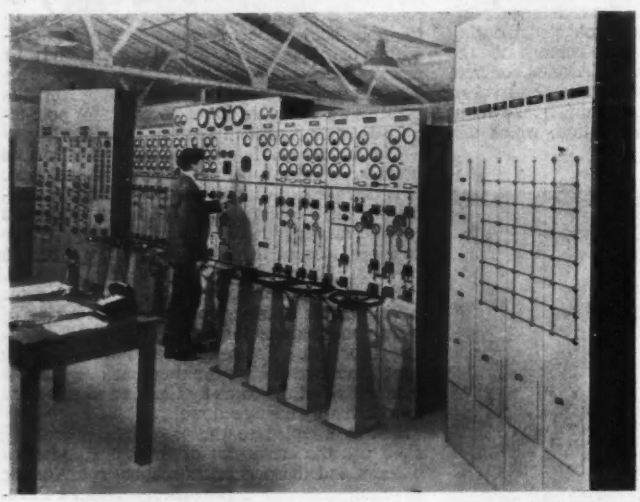


Fig. 6—Test plant control room from which any of the sets can be started up and paralleled to give the required test output

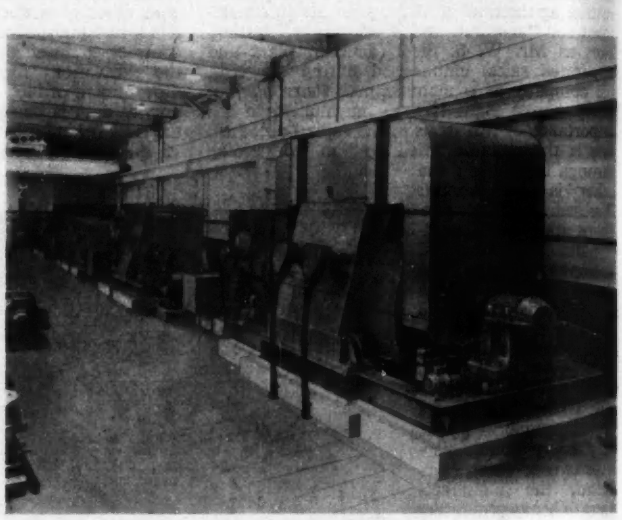


Fig. 7—Machine room for test supplies. In the foreground is the 20,000kVA motor alternator set

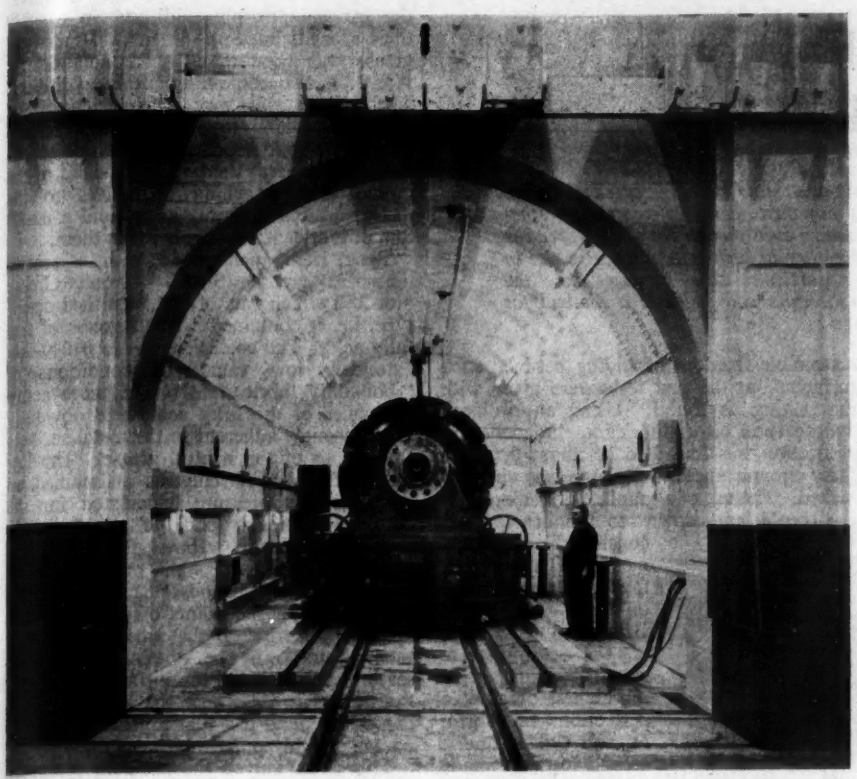


Fig. 8—A rotor in the balancing and overspeed tunnel. The steel doors have safety interlocks and the driving motor is in a separate room beyond the tunnel

tions. Special low power factor polyphase wattmeters are provided both for transformers and for alternators tested as synchronous motors. For machine testing, enclosed test houses, which contain both the instruments and controls conveniently grouped, have been built adjacent to the test stations, so that decisions can be made in a quieter atmosphere than is usual in heavy machine testing.

Balancing and Overspeed Test House

Among the interesting test facilities that have been provided in the Rugby works are those contained in a new rotor balancing and overspeed test house which was commissioned in April. It was designed primarily for rotors of turbo-alternators and replaces the old test pit, which was actually part of the turbine factory, but it can accommodate water-wheel alternator rotors up to 14ft in diameter as well as the largest turbo-alternator rotors so far envisaged.

The central section of the test house, which is an isolated building away from the main factories, is the overspeed tunnel itself. It is 18ft in internal diameter and 48ft long, and is built of reinforced concrete, backed by timber and sand. The driving motor and gearbox are contained in a compartment separated from the tunnel by a bulkhead. At the opposite end is a loading shop. Rotors are brought to the test house by railway trucks, from which they are lifted by means of a 120-ton crane, and lowered into bearings mounted on motorised carriages which move under power along a rail track into the tunnel. Inside the tunnel (Fig. 8) hydraulic jacks take the weight off the bearing carriage wheels, and the carriages are then bolted down.

Although the drive from the gearbox is transmitted by means of a long torque shaft, which in effect provides a flexible coupling, it is important that the alignment of the rotor is correct, otherwise false readings of apparent balance would be obtained. To simplify the alignment procedure the end of the gearbox shaft is fitted with an accurate, easily rotatable, lining-up disc. With the help of a clock gauge attached to this disc the rotor coupling face can be lined up very rapidly, with a considerable reduction in the total time required for the test.

A wide speed range is required because the test house has to deal with both high and low-speed rotors; it is achieved by the use of a step-up gearbox with several sets of gear ratios. The 3000 h.p. (peak) d.c. driving motor is supplied from the generating plant in the central test generating station, and only the exciter set and "Amplidynes" are installed locally. Smooth acceleration is achieved by Ward-Leonard control; equally important is ease of regenerative braking, using the same controls, whereby the largest rotor can be stopped in a few minutes.

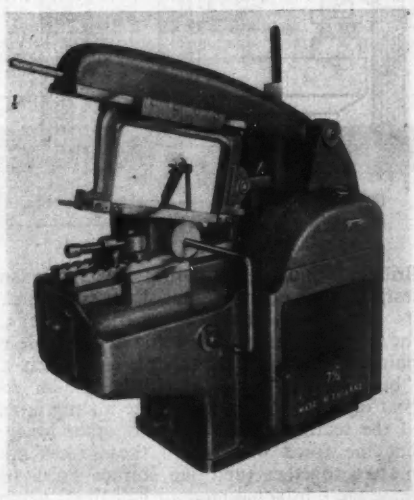
The controls are grouped in a specially designed desk (Fig. 9) in a separate compartment, which also contains indicating lamps to show that the extensive gravity-fed lubricating system is functioning correctly. A system of interlocks on all doors is designed to prevent the possibility of anyone being in the tunnel while a rotor is revolving above inching speed. The right-hand panel of the desk houses the electronic balancing gear. No provision is made for visual observation or for any mechanical connection with the rotor or its bearings. Seismic vibration pick-ups mounted on the bearing pedestals generate a voltage which operates direct-reading instruments in the control room. A vibration amplitude of 0·0001in can be readily detected, and the angular position of the out-of-balance forces at each end of the rotor, relative to an arbitrary position on the shaft, can be accurately measured. This facility enables accurate balancing to be achieved in a very few runs, before the rotor is subjected to overspeed.

Fig. 9—Control panel for balancing and overspeed tests. The balancing controls and instruments are in the right-hand panel. The main controls and indicating instruments are in the central portion, while the left-hand panel carries C.R.O. equipment and temperature indicators

While a rotor is in the test house for balancing and overspeeding, certain other processes and tests can be applied. A heavy current d.c. generator is installed for heating and drying out rotor windings, and the appropriate instruments are mounted on the left-hand panel of the desk. A high-voltage transformer and regulator provide for high-potential tests on rotor windings. Insulation resistance to earth and winding resistance can be measured while the rotor is still inside the overspeed tunnel. Forced ventilation of the tunnel is provided through the horizontal ducts, which can be seen one on each side of the rotor.

Hacksawing Machines

The construction of the "Volex" hacksawing machines, which were introduced in two sizes by B. Elliott and Co., Ltd., Victoria Works, Willesden, N.W.10, some five years ago, has been changed to increase the capacity of the machines. The larger machine is now capable of cutting 10in diameter or 7¼in by 11¼in rectangular material. The smaller machine, illustrated below, is capable of cutting 7½in diameter material. In the new design the smaller machine is also



Hacksawing machine of 7½ in diameter capacity with two cutting speeds, variable rate of down feed and automatic return at end of cutting cycle

fitted with a dashpot, which gives variable rates of down feed and automatic return of the saw blade after completion of the cutting cycle.

The machines are generally similar in construction, having a rigid box-shaped cast base in which the motor, drive and coolant pump and tank are enclosed. Drive is transmitted through twin vee belts and helical gears, and provides two cutting speeds of 80 and 115 strokes per minute on the small machine and 75 and 100 strokes per minute on the 10in machine. The saw bow is carried on wide guides which can be adjusted to take up wear. Both of the crankpins as well as the main drive shafts are mounted in ball bearings.

Saw feed is hydraulically controlled by two levers on the dashpot. One of these levers is linked to an automatic trip to raise the bow on completion of the cutting cycle. The other lever regulates the rate of down feed, the dashpot being arranged to lift the blade on each return stroke.

Measurement of Friction at Very Low Speeds

By A. G. TARRANT, O.B.E., F.INST.P.*

The harmful effects of friction are commonly associated with high speeds, because of the loss of power, heating and wear, that may then ensue. There are, nevertheless, cases when friction is a matter for concern even though the sliding speed is very low: the "boundary lubrication" necessary in such cases may give rise to special problems. The author mentions a particular case, indicates how the coefficient of friction was measured, gives results and suggests a method for further investigation.

IN the routine testing of concrete the quality of the concrete is customarily assessed by measuring the failing load of a cubical specimen when tested to destruction in compression, and it is important that the platens of the testing machine shall bear evenly over the faces of the test cube. For that reason, it is laid down in the current British Standard (B.S. 1881 : 1952) for the test, that one of the platens shall rest against its abutment through a spherical seating, the centre of the sphere being at the middle point of the face of the platen. Such a "ball seating" will allow the platen to bear evenly over the cube if the mating faces of the seating move over each other freely, but the force with which these faces are pressed together (and the surface finish of these faces in some modern machines) made it very doubtful whether any reasonable freedom was actually enjoyed by the platen when under load.

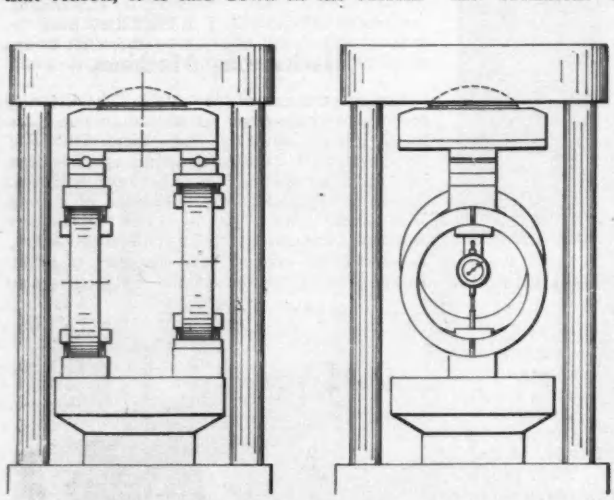


Fig. 1—Arrangement for measuring the freedom of the platen. The two proving rings are of differing stiffness

The freedom of the platen was therefore measured using the arrangement shown in Fig. 1. The two proving rings were of different stiffness, one being five times as stiff as the other. On applying load to the machine, the two rings were deformed through different distances, thus causing the platen to rock on its seating. The difference between the loads carried by the two rings gave the couple required to cause the platen to move, whilst the sum of these loads gave the total load on the seating. From these two quantities the coefficient of friction could be readily calculated, with results that are of some interest.

Before the first test the seating was opened up for examination, and the finish of the mating faces was found to be very rough, with contact occurring only in a very narrow irregular ring. It seemed idle to expect any reasonable freedom of sliding between such surfaces, but the first tests were made with the seating as found. Using an ordinary hydrocarbon oil as lubricant, the coefficient of friction was found to be about 0·6 ; in these circumstances, the platen was virtually locked. The use of a graphite grease brought the coefficient down to about 0·15—a considerable improvement, but still imposing too much constraint on the platen.

The mating surfaces of the seating were carefully refinished to the highest obtainable perfection of form, fit, and polish, and a second test was made with ordinary hydrocarbon oil. It was at first somewhat disconcerting to find that the coefficient was almost the same as before : the correction and polish of the mating surfaces had made no significant difference. It was then realised that, in the absence of any hydrodynamic forces which could maintain the oil film, the surfaces were coming into solid contact, and the ordinary laws of solid friction would apply—that is, the coefficient of friction would be independent of the distribution of load over the loaded area. The value obtained—about 0·6—was, in fact, the coefficient of friction for steel sliding on steel, and the value for graphite was lower merely because of the particular solid friction properties of that substance. Obviously, a true film of lubricant could only be maintained between the surfaces by the use of a lubricant which would adhere strongly to them.

A special oil was tried, containing "extreme pressure additives." (These are sulphur or chlorine compounds whose primary function is to react with the surface of a metal to form a protective film under conditions of heating due to working at high bearing loads.) There was only a small reduction in the friction : the conditions of very slow motion—about ¼in per hour—were such as to cause no appreciable heating, and there was therefore no opportunity for the extreme-pressure additives to exercise their special function. A neutral lime-base grease was tried (Shell "Rhodina Grease No. 2"), also containing "E.P. additives." The friction was very much reduced, the coefficient falling to about 0·055. It was clear that, apart from any effect due to the "E.P. additives," the polar molecules of the grease were attaching themselves to the metal surfaces so firmly as to hold a useful film of lubricant in place between them.

Tests were then made with a second lime-base grease (Shell "Livona Grease No. 3") which was of the "finished acid" type, i.e. it contained a small excess of free fatty acid. The coefficient fell to 0·040—an extremely low value for conditions of "boundary lubrication." The more active molecules of the fatty acid were obviously more strongly adherent to the metal surfaces than those of the neutral grease. The low value of the coefficient was maintained up to a bearing pressure (calculated for the whole area under load) of about 1000 lb per square inch. Above that limit the coefficient increased as the molecular bond between the grease and the metal began to break down at the points of greatest stress. It was therefore clear that freedom of movement would only be obtained, in a ball seating of this kind, if the surfaces are so well finished as to distribute the load as evenly as possible, and if a lubricant is used which contains highly polar molecules.

This result solved the problem presented to the writer. It was clear that the platen could be given a very satisfactory freedom by ensuring that the surfaces of the seating were true to form, well mated, and polished, that the bearing pressure was kept below 1000 lb per square inch, and that a grease was used that contained free fatty acid. The work in which the writer is engaged does not justify a greater expenditure of time on the study of friction in general, but the method of test could be of much use in any such study. For more extended work, it would be desirable to modify the simple set-up illustrated in Fig. 1. Objections to this arrangement are that the crucial quantity is obtained as a difference between the readings of two proving rings, that each test requires the services of three observers (one to read each proving ring and the other to operate the testing machine), and that many testing machines have insufficient headroom to accommodate the rings.

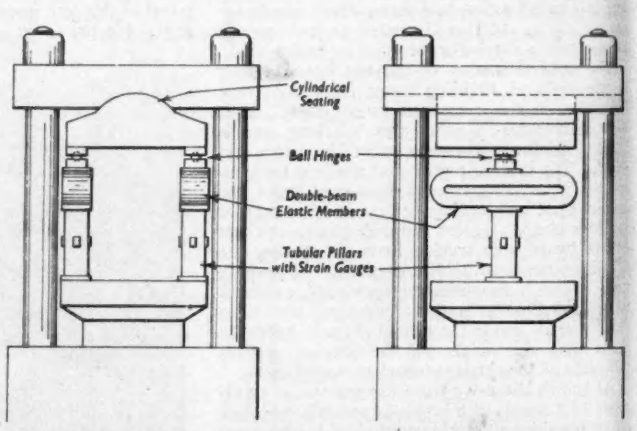


Fig. 2—Suggested arrangement for long-term research. Cylindrical seatings take the place of spherical ones and double-beam elastic members of the proving rings

An improved set-up is illustrated in Fig. 2. Here the proving rings are replaced by double-beam elastic members (one being, of course, much stiffer than the other). The loads are measured by supporting these members on tubular pillars of appropriate thickness

* Road Research Laboratory, Department of Scientific and Industrial Research.

carrying electric strain gauges. It is then possible to indicate, and to record, both the differences and the sum of the loads directly. A further improvement is that the spherical seating is replaced by a cylindrical seating, so that the velocity of sliding is everywhere the same. Provision can easily be made for fitting liners to the seating so that frictional effects can be studied with different materials. It is felt that, as so modified, the method would be a really useful tool for systematic research on friction at very low speeds.

ACKNOWLEDGEMENTS

Thanks are due to my colleagues who assisted in the tests ; to Dr. D. Tabor, of Cambridge, for his invaluable advice ; to Mr. W. Pohl, of the Shell Oil Company, for supplying the special greases, and to the Director of the Road Research Laboratory, for permission to publish this article.

Air Traffic Control Tower at Hatfield

AIR traffic control at the de Havilland airfield at Hatfield has been improved by the putting into commission, on June 21, 1954, of a new control tower. Previously control was carried out from a converted office at the top of the service school building. The problem of efficient traffic supervision is an important one at Hatfield. Situated on Amber 2 airway, just inside the London control area, the aerodrome does most of the development flying for the de Havilland aircraft, engine, and propeller companies.

Our first illustration shows the tower, which is situated at the south-west corner of the new flight test hangar (see THE ENGINEER, January 23, 1953, page 127). From the control room 65ft above the runway there is an excellent view of the aerodrome and of the surrounding district. The windows, which do not open, are made from Pilkington ¼in "Antisun" plate glass, which absorbs 50 per cent of the heat from the sun. Efficient sound proofing is obtained by lining the walls and ceiling with "Celotex," and is further improved by the heavy construction of the building and by having the control room set back so that it lies in the "sound shadow" of the parapet. The main structure contains the aerodrome manager's office and briefing and rest rooms for the crews.

We show the control desk in our second illustration. In the centre of the panel is the d.f. indicator, immediately beneath it are the lights of the instrument landing system. On either side are positioned six loudspeakers belonging to the communications sets. To the right are a barometer and an altimeter, wind speed and direction indicators, and the switches for runway and obstruction lighting. The internal telephone dial in the centre of the desk is flanked by the frequency selector switches. R/T and internal telephone handsets are stowed on hooks just below the edge of the desk.

The room is fully air conditioned and the ventilation louvres can be seen extending along the window sill. Two controllers are normally on duty, each being able to deal independently with all radio equipment and the internal and external telephones. While the average traffic is not heavy, this dual arrangement is of great value during peak periods. To avoid disturbance to the controllers during servicing, the equipment itself is positioned beneath the control room.

A twin-channel, remotely controlled v.h.f. direction finder, type "A.D. 200," by Marconi's Wireless Telegraph Company, Ltd., has been installed. This supersedes an earlier set, made by the same company, which had been in service at Hatfield for the past 4½ years. The new site for the aerial ensures greater accuracy and, being adjacent to the runway, will home pilots on a straight run-in for landing.

There are two sets of v.h.f. communications equipment ; one is a Marconi set operating on frequencies of 123·3, 122·5, and 131·3 Mc/s, and the other is by Pye Telecommunications, Ltd., operating on 123·3, 122·5 and 117·9 Mc/s. The Marconi set consists of a twin-channel 50W "TGV 472A" transmitter, twin-channel "R.P. 47C" receiver, and a low-power "H.16.A" transmitter/receiver. The Pye equipment consists of a 50W "PTC 751" transmitter/receiver and two low-power "PTC 704" transmitter/receivers.

An instrument landing system, also by Pye Telecommunications, Ltd., provides an approach using azimuth approach and glide path transmitters and an inner marker transmitter, all of which are situated at Hatfield, and an outer marker transmitter at Panshanger, 5 miles to the north-east.

In addition, there is an "R.V.A. 492" magnetic tape recorder, supplied by the Trevor-Johnstone Company, Ltd. Equipped with an extra broad tape and transverse scanning, it can run continuously for 192 hours. This, together with the control desk, by Pye Telecommunications, Ltd., and a special eight-day clock, by Thomas Mercer, Ltd., complete the equipment at present installed.

PROTECTIVE DUTY FOR COLOURED SHEET GLASS.—The Board of Trade is considering an application for an increased protective duty on flashed sheet glass, consisting of a layer of coloured or opal glass on a base of clear glass, and on sheet glass of the kinds commonly known as signal green, signal yellow, and pot opal or solid opal. Representations about this application may be made to the Board not later than September 4, 1954.

The control tower, which also contains the aerodrome manager's office, crew briefing and rest rooms. The fire station is in the foreground.

Control desk with d.f. indicator in the centre and i.l.s. indicator lights beneath it. To the right are the barometer, altimeter, wind speed and direction indicators

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"YE SHALL BE AS GODS KNOWING GOOD AND EVIL"

Those who hold that man has been rendered no happier through the possession of all those many material things that scientific discovery and engineering invention has brought to him can hardly be refuted. For happiness is a dynamic rather than a static condition. It is not a fixed state that can or cannot be attained. Man is happy, not because things are good, but because they are getting better. He is unhappy, not because a situation is bad, but because it threatens to become worse. Nor upon that basis can it really be argued that, because year by year engineers add to the output of labour and so add continuously to the possessions a man may aspire to buy, happiness is thereby being created. For in relation to possessions, just as in Newton's laws of motion, action and reaction are equal and opposite. The delight felt in the recent acquirement of a new radio is balanced by the fear that through an open window or a thin partition there may flow in upon us an unwanted programme from our neighbour's similar purchase; it is pleasant to drive the new car until crowded traffic upon inadequate roads frays the temper to distraction! Moreover, not all that scientists and engineers have made is altogether welcome. Maybe we are rendered happier by the knowledge that our Forces are armed with tanks and guns, ships and aircraft, the means for germ or gas warfare, atomic weapons and the hydrogen bomb. The happiness is overbalanced by the fear that an enemy may use just such weapons upon us!

But when those who look back nostalgically to supposedly happier days long past start blaming scientists for troubling the world by their discoveries and preaching to them that they ought to have the moral sense to pick and choose amongst the knowledges they present to the world the ground is altogether different; and the argument is no longer rational. For knowledge, in itself, cannot possibly be evil. Knowledge is neutral. Whether it is good for man to acquire it depends, not on the knowledge itself, but upon the use man makes of it. Adam and Eve ate, not of the tree of knowledge, which would have made gods of them, but of the tree of knowledge of good and evil which merely made them, as gods, able to choose between good and evil. It is for man to decide how knowledge shall be used. Moreover, the attack is largely misdirected. It is not scientists who have presented the world with great bridges, railways, aircraft, telephones, radio sets, refrigerators, guns, fighter aircraft, rocket weapons, and hydrogen bombs. They only provided certain basic knowledge. More often than not, indeed, their contributions to the making of things like locomotives, cars, dams for water supply or hydro-electric power, pylons, motorways, and many other productions that have been or still are criticised as evil and destructive, have, in reality, been very small indeed. Such scientific knowledge as was available to Parsons was not in itself nearly sufficient for the production of a practicable steam turbine. The practicability of making a hydrogen bomb would still be a scientist's dream if engineers had not devised a suitable plant. Most of the scientific knowledge upon which engineers' designs are based has, indeed, been supplied not by scientists, but by engineers themselves. For in technology advances can be made more rapidly than in pure science. Its researches are devised to attain particular and limited ends; whereas in pure science the front is broad, the end is not clearly seen. Within engineering pure science, in fact, supplies no more than the spark that may explode into vast developments of technology undreamed of by the scientists. It is engineers, not scientists, at whose door should be laid the blame or praise for the material enrichment of mankind. It is against them that the critics should thunder (and have in the past thundered) in moral indignation because the countryside-defiling locomotive, the new-fangled dangerous and horse-frightening car, the Nature-destroying dam, the noise-shattering helicopter, or the monstrously destructive hydrogen bomb have appeared upon the earth. Yet who are engineers that they should take decisions as to what they should or should not make? They are the servants, not the masters, of the community. Pure scientists, indeed, may be so situated that they can follow their own bent untroubled by what the world thinks of their discoveries. Not so the engineers. What they make they must sell to earn their livings. They offer wares at a price. It is the consumer who decides whether or not to buy and what shall be made; and woe betide the engineer who offers the people what they do not want at a price they will not afford to pay. Was it then wrong for engineers to make hydrogen bombs when scientists had found the key and Governments offered to buy? Would it not have been far worse for them to refuse; to abrogate to themselves, a limited number of men with specialised knowledge in their own professional field, but no qualifications for making judgements elsewhere, the right to decide what it is good or bad for man to have? Maybe it would have been better if scientists had never discovered the secret of the hydrogen bomb (though we do not think so). But having discovered it, we hold that they too would have been just as morally wrong to conceal the knowledge as engineers would have been wrong not to make the bomb at the behest of governments.

It is for communities and governments to decide what use is to be made of new knowledge. If scientists deem it to be bad they can but deplore it. Engineers, however, have a livelier answer. Knowledge is neither good nor evil; but it is power. If it can be applied for evil and destructive ends it can also be applied constructively. The rapid development of aircraft was stimulated by wars; yet to-day annually far more people are transported by civil airlines than ever travelled for warlike purposes. Far more explosive has been touched off in the making of tunnels, the quarrying of rock and for other civilian purposes than was ever used in war. Already the production of radio-active isotopes at Harwell may have saved more lives than atomic fission took away at Hiroshima and Nagasaki. Knowing the ingenuity of engineers, we do not doubt that the means to apply the hydrogen fusion process to useful constructive purposes will be found.

LIMITS ON RESEARCH PROFITABILITY

During the last two centuries, the advance in man's scientific knowledge and in his application of it to useful ends has been immense. Indeed, in retrospect, the pace of advance seems to have accelerated. Each new discovery, each new generalisation seems to have stimulated further discoveries and further generalisations. Yet it may be that the acceleration is more apparent than real, that it is a function of the numbers of people engaged in science rather than a consequence of an increase in knowledge facilitating an increased rate of acquirement of knowledge. In comparison with the effort expended, it is by no means impossible that the rate of advance is slowing down. For certainly within a field restricted to technology, it can be seen that a law of diminishing returns applies. When Watt patented the separate condenser, the returns upon research into

the operation of the steam engine were very high indeed. What would they be now, over 150 years later? Again, the returns upon Parsons development of the steam turbine were immediately vast. But, though there is still room for advancement, there is not now very much room. The return in terms of thermal efficiency of pushing up pressures and temperatures is falling sharply away, whereas the practical difficulties continue to mount. Quite soon, maybe, further development will come almost to a halt. By contrast, researches into the application of atomic power have scarcely begun and the probable returns for the effort expended loom immensely large ahead. But, of course, such illustrations may not be applicable to purer science, where wider generalisations, demanding long periods for gestation, each bring immense returns.

Technological research, by its very nature, is less likely to produce these great generalisations that are so valuable to engineers, than is purer research. Any experiment is likely to suggest several roads for further advancement. But in technology, only those that seem to lead more obviously towards the particularly desired end of improving a particular machine or group of machines or devices are followed up. Thereby advance becomes the more rapid by virtue of its restriction to a narrower field. But the key to wider generalisations lies not in narrowing but in widening research. Technological research, for example, has produced a generalisation about the nature of the creep curve of a metal. But the precise curve for any given metal can only be discovered by experiment. Yet though the multiplication of such experiments is the obvious road to the rapid technological advance of machines and devices operating at high temperatures, it is unlikely to lead to any wider theoretical generalisations about creep. The attainment of those wider generalisations is much more likely to come from those studies of the structure of metals that pure scientists, rather than engineers and metallurgists, are undertaking. Yet immensely valuable though such wider generalisations are, they have their defects. They are, unfortunately, seldom true to life. That simplicity which is their virtue has been gained by the assumption of conditions that cannot, or do not, rule on earth. How splendid it would be were all gases to behave like "perfect" ones! Unfortunately they do not. So that if the performance of machines in which the temperature, pressure and volume of a gas is altered is to be pushed up to the highest attainable value, experiment must still be made into the precise behaviour of the particular gas concerned. Much technological research to-day, in consequence, must be directed towards illuminating the imperfections of wide generalisations. Accurately to assess, for example, the power of a lever we cannot depend wholly upon the simple laws of mechanics. For there will be friction to contend with. True, we may devise a theory of lubrication, so that, despite the friction we can still calculate the forces acting upon the lever. But that generalisation about lubrication will still be imperfect. It will contain a term dependent upon the lubricant. And so on. Moreover, each derivative generalisation is less widely useful than its forerunner. A knowledge of mechanics is desirable for the proper use of any form of lever. But only in a small proportion of those uses will it be necessary to account with precision for the friction; and only in a small proportion of that proportion will an exacting choice of lubricant have to be made. Yet the effort needed to win sufficient knowledge to formulate the derivative generalisations is at least equal to, and very probably far surpasses that required to reach the original! The diminished return for effort is here plain to see.

The main value, of course, of an accepted generalising theory is that it facilitates exact calculation and gets rid of rule of thumb approximations. But it has another. It rids the world of a load of recorded information about individual experiments and inexact theories. How many librarians, we wonder, appreciate that point? How many books still lie on library shelves, how many references to technical journals and papers still find a place in the current files when, in fact, reference to them has become only of historic interest? How many students, as a consequence, have waded through piles of out-dated information subsequent to the publication of documents that have made the material out of date? Yet, despite the help of generalisations, the weight of human recorded knowledge still piles up. It is already a matter of grave difficulty for a research man to be sure that he has laid his hands, before beginning a research, upon all published information that has relevance to it. Sooner or later, it may become worthless to pile up more. For it may become quicker and cheaper to repeat an experiment, even a costly one, than to search the records for something which, after all, may not be there, an example of a diminished return brought about by the super-abundance of material. Nor is that the only embarrassment of a super-abundance. If one wants to know the shape of a wood, it may be simpler to conduct one's own survey of a few of its more prominent trees than to attempt to pick out particulars of those trees from a mass of material precisely locating every bush and tree in the wood! Wealth of material has, too, another defect. Who, upon entering a great library has not, at times, felt discouraged and inferior. What is his little knowledge against the enormous store there of man's knowledge as a whole? How many men, we wonder, having originated an idea worth pursuing have been put off pursuing it through conceiving their abilities, puny by comparison with the effort that created a library, unequal to the effort, or the thought itself obviously trite and already rendered threadbare by the work of others. Perhaps, librarians as a class being an enthusiastic and encouraging group of men, not many. But there again, sheer weight in recorded knowledge may lead to diminishing returns.

Literature

Britain's Railways To-day. Edited by JOHN ST. JOHN. London: The Naldrett Press, 91–93, Baker Street, W.1. Price 15s.

THE purpose of this book is to provide an insight into the working of British railways as they are at the present day, the aim being to give the reader a picture of how the railways function, making reference to both their problems and progress. With this end in view, the editor has secured the co-operation of practical railway men, each one of whom contributes a chapter on some specific phase of railway work on which he is engaged: thus, the book is written by people who actually do the job or can be expected to know by experience how it is done.

In order to bring to notice the scope of this book, it may be as well to enumerate the chapters which go to tell the story of how the railways function. There are in all fourteen of them, prefaced by a charmingly written and impressive introductory note by D. S. M. Barrie, M.B.E., public relations department, British Transport Commission. Under the general heading Motive Power, there are four chapters on, respectively, the steam locomotive, steam locomotive design, electric trains and diesel and gas turbine locomotives. Under the next heading, The Permanent Way, chapter 5 deals with the track, and chapter 6, railway construction. Traffic Working is the next sectional heading, containing two chapters on signalling and traffic control and the guard. Next, under the heading Transport of Passengers and Goods, come four chapters on rolling stock, railway architecture, the passenger station, and parcels and freight. The final section, Engine Building and Research, comprises chapters on the birth of a train and railway research. Interspersed between some of the main chapters there is included a series of railway profiles, taking the form of pen sketches of selected railway personnel, such as an engine crew, an electric motorman, and a station master, to name a few of the seven described. To support this reading matter extending over 183 pages of text, there are 184 illustrations, including drawings and photographic views, fully adequate for requirements and well produced.

It will be appreciated from the foregoing that much has been attempted within the compass of a book of moderate size, and it may at once be said that, in the main, the material presented is of considerable interest and will be undoubtedly helpful to those who delight in "watching the trains go by" and aspire to know something of how the locomotive is made, how it works and what the back room boys do behind the scenes. Something about the railway carriages they travel in and how they are protected during their journeys by the railway signalling system may be expected to be informative reading to the many who take a more or less superficial interest in our great railway enterprise.

For the most part, the pages of this book have been read with pleasure and have been found to satisfy requirements. On the other hand, in certain cases some rather curious omissions are in evidence. For instance, under the section on motive power no mention is made of the very great improvements made in the modernisation of motive power depots during the last thirty years or so; no one thing has done more to enhance the availability of modern motive power than the improved layout and equipment of engine terminals, yet it entirely escapes notice. Considering the track, the subject of sleepers attracts attention. The writer discusses timber sleepers most commonly used and refers to the use of those of prestressed concrete as a possible alternative. Surprisingly, however, no mention is made of steel sleepers, though considerable attention has been given to this type in the past, while on certain overseas railways they are very largely employed. Reference may here be made to a particularly informative paper by R. Carpmael, read before the Institution of Mecha-

nical Engineers in 1931, entitled "The Manufacture and Use of Steel Railway Sleepers," which, together with the discussion —itself of much interest—was published in THE ENGINEER of December 18 and 25, 1931. In the same chapter it is perhaps rather amusing to read that in 1948 "it was decided after much consideration to adopt flat bottom rail as standard," a type of rail long a standard the world over. Turning to the chapter on "The Birth of a Train," which incidentally deals only with the construction of the locomotive, a rather unlooked-for slip comes to notice. The author writes: "The barrel portions of the cylinders (of cast iron or steel) are bored to take the pistons; the steam chests are bored to take the piston-valves." If this statement had been made by someone other than an engineer associated with locomotive manufacturers, it might have escaped question. In the first place, cast steel cylinders are not bored to take the pistons; they are bored to receive cast iron liners in which the pistons work. A piston would not work satisfactorily in a cast steel cylinder barrel. Similarly, the steam chests are not bored to take the piston valves: they are bored to take cast iron liners or bushings in which the piston valves work; further, this is standard practice, no matter if the cylinder castings are in steel or iron.

Looked at in its broadest aspect, the book will, it is hoped, be read by "the man in the street," who can do so without getting out of his depth. It is desirable that the ways of our railways should be understood by their owners, who it is equally desirable should learn to appreciate and not depreciate this great national asset.

A Textbook of Metallurgy. By A. R. BAILEY. London: Macmillan and Co., Ltd., St. Martin's Street, W.C.2. Price 30s.

SPECIALISED branches of metallurgy are now so numerous that the author of an introductory textbook is well advised to confine himself to a discussion of the fundamental principles underlying physical and process metallurgy, with the addition of such practical details as may be required to illustrate their application. Mr. Bailey has adopted this method with marked success. The first six chapters of the book deal with physical aspects of the subject, for example, crystallography, atomic structure, constitutional diagrams and microstructure of alloys. In the next five, dealing with the extraction and refining of metals and with related subjects, chemical and physico-chemical considerations have a prominent place. The rest of the book deals for the most part with mechanical forming operations, the testing of metals and methods of temperature measurement. This list gives but an inadequate idea of the contents of the volume, which is replete with relevant information making it an excellent introductory textbook of general metallurgy. It is not intended to stand alone, for every chapter ends with a well-chosen list of books for additional reading. Some subjects are treated rather fully, for example, phase equilibria and constitutional diagrams receive extensive treatment, illustrated by a large number of diagrams with drawings and photographs of structures. On the other hand, some highly theoretical conceptions of metal physics, very rightly, get just sufficient mention to make the reader aware of their existence. From a practical standpoint one could wish that the principles of heat-treatment of steel had been set out in more detail. Steelmaking processes are described at length, so also is the mechanical treatment of steel. There is a fairly long description of heat-treating appliances, but very little about heat-treating processes and their effect on mechanical properties of carbon and alloy steels. The same applies to the effect of heat-treatment on the properties of non-ferrous alloys. In fact, it seems that "metal winning" has had priority over "strength of materials" in the inevitable competition for space.

However, there are ample references to books for additional reading on this, and on many other subjects that may appear to some to have been scantily treated. The book has been written to conform to certain examination requirements, it is well illustrated and contains a large collection of examination questions. It should prove to be of great value to students, and as an introduction to general metallurgy it will serve a useful purpose. Its reasonable price for a book of over 550 pages should add to its popularity.

Resistance des Matériaux. By R. L'HERMITE. Paris: Dunod, 92, Rue Bonaparte, (VI^e). Price 8,400F.

THIS book, the author of which is the director of the French Laboratoires du Bâtiment et des Travaux Publics, constitutes the first volume of a series of four, which the author hopes to write during the next few years. This volume is devoted to the classic theories of elasticity, elasticity in two and three dimensions, methods of computation of structures, theories of flexure and torsion, theory of flat plates, and theory of shells. The other volumes will be respectively concerned with the theory of stability, physical mechanism of metals, and theory of plasticity. The author appears to have taken great trouble to make the book comprehensive; judging by the considerable bibliography* at the end of each chapter he has consulted a great many previous works on the subject, and despite very considerable pruning of the matter at his disposal, has nevertheless finally been left with a volume of some 900 pages divided among ten chapters. The book is definitely not a "course" in strength of materials as normally found in many text-books on this subject; rather may it be termed a book of reference for specialists, designers and physicists. To this end each chapter of the book appears to have been drawn up in such a way as to be virtually self-contained, drawing little on previous chapters. No worded numerical examples are given, but, on the other hand, an unusual number of "special cases" are dealt with in detail. In the theoretical treatments outlined, use is made of tensor notation, but not in a degree inconsistent with the acquaintance with this notation likely to be possessed by most readers of the book.

To deal with the contents of the book in rather more detail: the first chapter concerns the basis of the theory of elasticity, of which some historical account is given. Apart from features commonly found at this stage in work on elasticity, such as the account of equilibrium and deformation of continuous media, it is pleasing to see that attention is given to generalised non-linear elasticity, the treatment of contact phenomena following Hertz, non-uniform heating, and the elasticity of non-isotropic bodies. It is worth notice here that this latter aspect of elasticity is considered in subsequent chapters in relation to the special topics with which they treat. This, in the writer's opinion, constitutes a most necessary item of any up-to-date book, since the engineers' use of text-book information must in very many cases be applied to materials which are admittedly anisotropic. The second chapter enlarges on the subject of two-dimensional (plane) elasticity, treating in detail aspects mentioned generally in chapter I. The use of polar, curvilinear and oblique cartesian co-ordinates in the solution of the problems arising, is illustrated. A section is devoted to the consideration of multiply connected bodies in plane elasticity, and the effects of notches and grooves are considered. The third chapter deals with the general problem of flexure of beams, on more or less conventional lines, but with very full attention to special problems. The same remarks apply largely to chapter IV on torsion. In this chapter a feature is the section concerned with mathematical methods of approximation, making use of the calculus of finite differences, the calculus of variations, and relaxation and graphical methods. The fifth chapter outlines the theory of determinate structures. The necessary basic statics are covered, and the theory of equilibrium of wires is outlined. Determinate girders, arches, curved bars and springs are considered. A number of the classical methods of resolution of plane jointed systems and jointed systems in space are given. In chapter VI indeterminate structures are considered.

The general principles of study of indeterminate systems are outlined and are applied to problems concerning continuous beams and grids under a considerable variety of conditions. The seventh chapter continues with this general subject in relation to arches, rings, simple and complex portals and three-dimensional problems of indeterminate structures. In the eighth chapter a comprehensive study is made of the theory of flat plates. The ground covered is wide and in our opinion this chapter constitutes the best treatment of this particular problem which we have encountered in a textbook. It would be reasonable to make similar remarks concerning some aspects of chapter IX dealing with theory of shells. The general theory outlined here is treated with unusual thoroughness and is applied to a comprehensive range of problems.

There is little to criticise in the layout of the book. A particularly useful feature is the provision of a list of notation with each chapter, instead of the distribution of statements of notation throughout the text, as frequently occurs in books of this type. The expression of the author's general views, in the concluding chapter, on the fundamental issues of the problems discussed in the previous nine chapters adds to the value of the work as a book of reference, although it seems reasonable to suggest that this matter might, with advantage, appear as a preamble to the book at the end of the preface.

This book certainly displays many of the characteristics of the best English books on this subject, and has also a degree of uniqueness in its treatment and in the ends it is intended and framed to serve. It is to be hoped that an English translation will become available at an early date; meanwhile, we suggest that there are many who will find the trouble of consulting the French version well repaid.

* Itself, according to the preface, only a representative selection.

INVESTMENT CASTING.—We are informed that Guest, Keen and Nettlefolds, Ltd., and the Mercast Corporation of New York have formed a company under the name of Mercast (Great Britain), Ltd., to license firms in the United Kingdom and the British Commonwealth (excluding Canada) to use the "Mercast" process. In this method of investment casting, patterns of frozen mercury replace the more usual wax patterns, and it is stated to permit closer tolerances, smoother finish and the ability to make more complicated and larger castings than are practicable with the lost wax method. The registered office of the new company is at Albert Street, Bilston, Staffs, and the technical manager is Mr. Christopher Dykes.

Letter to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

SIR CHARLES PARSONS

SIR,—The following letter, dated July 20th, has been received and, in accordance with the writer's request, I hope you will publish it.

J. F. FIELD

Edinburgh, July 31st.

MONSIEUR,—Dans son numéro du 25 juin dernier, la revue THE ENGINEER, a publié une lettre que vous lui aviez adressée au sujet de l'oeuvre géniale de Sir Charles Parsons et où vous traitez notamment des premières applications du réchauffage de la vapeur en cours de détente et du réchauffage de l'eau d'alimentation. A ce dernier point de vue, vous voulez bien rappeler le nom de notre maison, non sans vous demander si c'était bien un souci d'économie de consommation qui avait inspiré ses conceptions. Nous croyons vous intéresser en vous fournissant, sur ces deux questions, des précisions.

Le 26 juin 1856, Benjamin Normand, ingénieur de notre maison, prit le brevet d'invention français no. 28278/16839. On y lit notamment ceci : " Dans les machines dites de Woolf, où la vapeur exerce son action expansive dans deux cylindres successifs de volumes différents, le refroidissement extérieur qui peut avoir eu lieu dans le premier cylindre et celui qui résulte inévitablement de la première portion de travail déjà fournie opèrent la condensation d'une partie de la vapeur. Cette vapeur ainsi mélangée intimement de parcelles liquides est d'un emploi désavantageux auquel ne remédient qu'imparfaitement les enveloppes de vapeur du second cylindre. Pour atténuer les défauts de cette vapeur humide, on la mélange quelquefois avec une certaine quantité de vapeur prise directement à la chaudière et dont on n'utilise pas ainsi tout le travail de détente. On donne aussi parfois à la vapeur, à sa sortie de la chaudière, un excès de température tel que, malgré le refroidissement dû à la détente, les températures moyennes, prises par les parois des cylindres, se trouvent supérieures à celles correspondantes à la pression initiale de la vapeur et qu'ainsi aucune condensation ne puisse avoir lieu dans les cylindres. Cette manière d'opérer, qui serait très avantageuse, n'est applicable que pour les basses pressions et avec un surcroît de précautions pour le graissage ; mais, avec la haute pression, la température de la vapeur étant déjà très élevée, une augmentation la porterait à un point où le graissage et la durée des garnitures seraient compromis." "Afin de remédier aux inconvénients ci-dessus," l'auteur propose trois solutions consistant à faire passer la vapeur, entre son échappement du premier cylindre et son introduction au second, dans l'un ou l'autre de trois appareils destinés respectivement à en éliminer les gouttelettes liquides, à la sécher ou à la surchauffer. Il appliqua cette dernière disposition quand il effectua, en 1860, sur le " Furet," la retentissante et féconde réalisation de la machine à double expansion avec réservoir de vapeur entre les deux cylindres et manivelles calées à 90° l'une de l'autre, au lieu de la course identique de Woolf et du calage à 180° de Randolph et Elder.

Dans une autre partie du même brevet, Benjamin Normand ajoute : " L'échauffement de l'eau d'alimentation présente aussi un avantage très sensible " et, à cet effet, il propose divers dispositifs permettant, sur une machine monocylindrique, de prélever une partie de la vapeur avant achèvement de la détente, puis il ajoute : " Dans les machines où la vapeur travaille dans deux cylindres successifs, une manière plus simple d'agir consisterait à en prélever une partie dans son passage du petit au grand cylindre pour la diriger dans l'appareil réchauffeur." Et il démontre, à l'aide de chiffres, l'avantage qu'il y aurait à opérer ainsi du point de vue de la consommation. Il n'est pas à notre connaissance que Benjamin Normand ait réalisé les conceptions exposées dans ce brevet en ce qui concerne le réchauffage de l'eau d'alimentation à l'aide de vapeur ayant déjà fourni du travail.

Jacques-Augustin Normand, alors à la tête de notre maison, ignorait totalement ce brevet de son frère aîné quand il pourvut de réchauffeurs d'eau d'alimentation—la vapeur réchauffante étant prélevée à mi-course du grand cylindre sur les machines à double expansion et avant l'introduction au grand cylindre sur les machines à triple expansion—tous les torpilleurs qu'il dessina et construisit à partir de 1887. Du jour où il eut connaissance de ce brevet, il proclama, en toutes circonstances, l'antériorité revenant à son frère en matière de conception. Au sujet de ces applications, il est difficile d'avancer, comme vous le faites, que " it is not clear whether they were motivated by fuel economy " quand on a lu les pages dont nous vous envoyons ci-joint une reproduction photographique et qui, extraites du catalogue de notre maison pour l'Exposition de 1900, avaient été rédigées par J. A. Normand lui-même. Aussi bien avait-il publié en 1893, dans le Mémorial du Génie Maritime, un important mémoire rendant compte d'expériences très étendues auxquelles il s'était livré sur un réchauffeur d'eau d'alimentation.

Sir Charles Parsons n'ignorait certainement pas les réalisations de J. A. Normand en ce domaine. Quand celui-ci livra, en septembre 1895, le torpilleur " Forban," qui fut le premier navire à réaliser la vitesse de 31 noeuds, la presse technique de Grande-Bretagne consacra à ce bâtiment des articles étendus, où l'extraordinaire et presque incroyable économie de consommation (due également à d'autres causes, dont la principale était le rendement élevé de la chaudière Normand) fut représentée comme le trait le plus frappant de cette performance. En juin 1904, notre maison livra le torpilleur no. 293, qui fut le premier torpilleur français à turbines, dont les plans avaient été établis par J. A. Normand et C. A. Parsons, dont nous avions construit la coque et la Compagnie Parsons les turbines et qui, comme tous nos torpilleurs depuis 15 ans, avait un réchauffeur d'alimentation.

Au cours de ces dernières années, le réchauffage de l'eau d'alimentation à l'aide de vapeur ayant déjà fourni du travail a pris un développement considérable dans les centrales thermiques. L'ingénieur auquel, en France, en revient le plus grand crédit est M. Emile Rauber. Il en a fait l'objet d'un mémoire présenté à la Société des Ingénieurs Civils de France et dont une analyse a paru dans le Bulletin no. 10 (Année 1953) de cette institution. L'auteur, qui, à cet égard, ignorait totalement les travaux de Benjamin Normand et ne connaissait que très succinctement, comme vous-même, ceux de J. A. Normand, a rendu justice, en particulier, aux réalisations britanniques.

Peut-être, Monsieur, voudrez-vous bien trouver quelque intérêt aux précisions qui précèdent et les juger dignes de former la matière d'une seconde lettre, rectifiant et complétant celle que vous avez publiée dans la grande revue anglaise.

Nous vous prions d'agréer l'assurance de notre considération distinguée.

Chantiers et Ateliers Augustin Normand,
Le Président du Conseil d'Administration.

A. AUGUSTIN-NORMAND

Le Havre, July 20th.

Admiralty Advisory Committee on Structural Steel

ON July 28th last, the well-known Admiralty Ship Welding Committee was dissolved and was replaced by a new committee to be called the Admiralty Advisory Committee on Structural Steel. The old committee was formed in the early part of 1943 " to consider and investigate special problems arising from the employment of welding in ships' structures and to advise on methods for their solution."

The need for such investigations arose from the spectacular and disturbingly frequent failures which had occurred in welded ships built during the war, mainly in America, at a time when welding was being more extensively used than ever before to speed up the production of ships. The significance of these failures in relation to merchant and warship construction in this country was immediately appreciated, and it was obvious that, although we had not had similar troubles, they concerned us very closely. The investigations carried out by the committee during its eleven years of operation covered all aspects of welded ship construction, including design, workmanship and material, as well as the effects of residual stresses and other factors. Full-scale bending experiments were carried out on eight " guinea-pig " ships, both at sea and under still-water conditions. The results of the comprehensive experiments in " Clan Alpine " and " Ocean Vulcan " have now become well known. The effects of welding on shipbuilding steel were also fully considered, as well as the properties of the steel itself. Full details of the experimental work and of the committee's findings are embodied in thirteen large reports published by Her Majesty's Stationery Office. The committee also issued three important memoranda giving guidance on the construction and repair of welded ships, and on the inspection of welds in the shipyard.

In general terms, the committee found that the failures were the result of several contributory causes. In the field of design it was found of the utmost importance to avoid all forms of notches and discontinuities, and to ensure full continuity by careful consideration of the design of connections. The importance of good workmanship coupled with proper supervision and inspection were emphasised, to prevent the occurrence of flaws and other defects which might originate fractures. It was found that close attention must be paid to the weldability and notch toughness of the steel. The committee felt that whereas it had been able to recommend adequate precautions in regard to design, workmanship and the technique of welding, the problem of recommending standards for adequate notch toughness in the parent steel was beyond its scope. Accordingly the new committee has been formed under the chairmanship of Sir Victor G. Shepheard, K.C.B., R.C.N.C., director of naval construction of the Admiralty, to deal particularly with the problem of brittle fracture in structural steel, under the following terms of reference :—" To make such recommendations as may be practical or desirable regarding the quality and testing of structural steels, with special reference to brittle failure and suitability for welded construction. To consider the programmes and results of current research in these fields and to institute any further investigations considered necessary."

The new committee is representative of a wide range of interests, not only in shipbuilding, but also in the other structural fields, and includes strong representation from the steelmaking industry.

Books Received

Petroleum Microbiology. By E. Beerstecher. London : Cleaver-Hume Press, Ltd., 31, Wrights Lane, W.1. Price 55s.

Coal, Its Formation and Composition. By W. Francis. London : Edward Arnold (Publishers), Ltd., 41, Maddox Street, W.1. Price 84s.

Prestressed Concrete. Third edition. By Gustave Magnel. London : Concrete Publications, Ltd., 14, Dartmouth Street, S.W.1. Price 20s.

Linear Equations in Applied Mechanics. By H. F. P. Purday. Edinburgh : Oliver and Boyd, Ltd., Tweeddale Court, 1. Price 20s.

Whillans's Tax Tables and Tax Reckoner 1954–55. By George Whillans. London : Butterworth and Co. (Publishers), Ltd., 88, Kingsway, W.C.2. Price 4s. 6d.

Structural Tests in Still Water on Riveted Dry Cargo Ship "Clan Alpine." Report No. R.7 of The Admiralty Ship Welding Committee. London : Her Majesty's Stationery Office, York House, Kingsway, W.C.2. Price 30s.

Present-Day Locomotive Working in Great Britain*

By O. S. NOCK, B.Sc., M.I.C.E., M.I.Mech.E.

No. XI.—THE " BRITANNIA'S " IN EAST ANGLIA—PART I

The accelerated express train services between London and Norwich provide the first example in this country of a group of train workings operated entirely by new British standard locomotives. The engine " diagrams " and the utilisation of locomotives in both passenger and freight service are of special interest at the present time, particularly as some of the passenger duties involve spells of quite hard running. In this article the author surveys the working as a whole

THE main line network of the former Great Eastern Railway, extending from London to the coastal resorts of Hunstanton, Cromer, Yarmouth, and Felixstowe, and linking up Cambridge, Ipswich and Norwich, constitutes a compact group of railways, with a passenger traffic fluctuating, from a steady stream between London and Cambridge, and London, Ipswich and Norwich all the year round, to a flood of week-end holiday travel to all the coastal towns for some four months in the summer. Twice in its history the Great Eastern has drawn the limelight upon itself by a complete and radical rearrangement of its passenger train services. The first occasion was in 1914 ; but then the almost immediate outbreak of war nullified the effects of this change, and soon compelled the cancellation of many trains and the deceleration of others. The second radical change came in rather more favourable circumstances when, in 1951, the Eastern Region of British Railways introduced a much accelerated and remodelled service between London, Ipswich and Norwich. This has since been followed by similar improvements on the Cambridge line.

The East Anglian lines have presented a locomotive operating problem for many years. Due to financial difficulties in the early days, many of the lines that went to make up the Great Eastern were constructed in less grandiose style than, for example, the London and North Western, and the Great Western. A legacy from those early days was a relatively low limit for locomotive axle loads, and up to the time of grouping, in 1923, the largest passenger locomotives in service were the Holden " B12 " 4–6–0s, having a total engine weight of 64 tons, and an adhesion weight of only 44 tons. Yet in the holiday season the maximum loadings of individual express trains were second only to those of the most popular Great Western West of England services. Over a period of many years the Great Eastern Railway had built up a magnificent tradition in locomotive construction and upkeep, and skilled enginemanship. Thus only was it possible to maintain running times on such trains as the old Norfolk Coast Express, which made its first stop out of Liverpool Street at North Walsham, 130·1 miles in 158 min, or the Hook of Holland boat express, which was at one time booked to cover the 68·9 miles from Liverpool Street, to Parkeston Quay in 82 min. Despite the relatively small engines in use, these trains were " timed " with loads up to 450 tons.

The London and North Eastern Railway introduced the three-cylinder "Sandringham " class 4–6–0 and later the general utility " B1 " 4–6–0. While both these designs incorporated a higher nominal tractive effort than the G.E.R. " B12 "—25,380 lb and 26,880 lb respectively—neither had the capacity to permit of really substantial acceleration of service. Over a period of nearly thirty years the locomotive running department of the Southern Area of the L.N.E.R. had had on the East Coast main line from King's Cross experience of large " Pacific " engines, with boilers of high steaming capacity, and for some time prior to nationalisation it had been felt that a " Pacific " design with a greater route availability than that of the Gresley " A1," " A3," and " A4 " classes would be ideal for East Anglia. Shortly after nationalisation some trials were made with a Bulleid light " Pacific " of the " West Country " class, which was loaned by the Southern Region. The " Britannia " was therefore in many ways the result of a long-expressed need on this particular group of lines. With an adhesion weight of 60¾ tons and a maximum axle loading of 20¼ tons it can traverse all the East Anglian lines south of Norwich. By courtesy of the Railway Executive, and with the ready assistance of Mr. L. P. Parker, motive power superintendent of the Eastern Region, I was enabled to make a comprehensive survey of " Britannia " workings at the height of the summer traffic in 1953, riding on them in both passenger and freight service. Although those responsible for locomotive operating in this area would probably deny most vehemently that sentiment plays any part in modern workings, they have, consciously or unconsciously, done a great deal to rekindle the spirit and traditions of the old Great Eastern Railway. Many times, too, in the course of these footplate journeys, my companions would draw attention to an old " D16 " 4–4–0, a " J15 " 0–6–0, or a " B12," adding some reminiscence of their younger days on the railway.

At the time of my journeys twenty-three " Britannia " class engines were allocated to the Great Eastern section, and of these thirteen were stationed at Stratford and ten at Norwich. The routes concerned are shown in Fig. 1. The regular diagrams allocated to these engines are shown in the tables opposite.

The nine regular Stratford diagrams require an average daily mileage per engine of 388, and the seven Norwich diagrams an average of 364 miles per engine. At Stratford the " Britannia " herself, No. 70000, is set aside exclusively for No. 9 diagram, the Continental boat train working, and like the Southern Region engine of this class at Stewart's Lane depot which is reserved for the " Golden Arrow " service to Dover, she makes a relatively low daily mileage. But there is a certain amount of national prestige attached to the working of these boat trains, and the lower daily mileage enables the engines on both Eastern and Southern Regions to be maintained in beautiful external condition, and as such a good advertisement for British Railways in the eyes of incoming visitors to Britain from the Continent. At Stratford, apart from the Continental working, ten regular engines are available to cover eight diagrams, and when the complete stud of thirteen engines is available two are spare and are used on other duties. A point of particular interest is that the regular engines are allocated to definite crews, both at Stratford and at Norwich depots. The practice of allocating engines to regular crews invariably results in a higher standard of performance all round ; but the length of run and the nature of train workings does not always enable this to be done, and at the same time to secure good utilisation of engines and economic working of crews. The railway geography of East Anglia, and

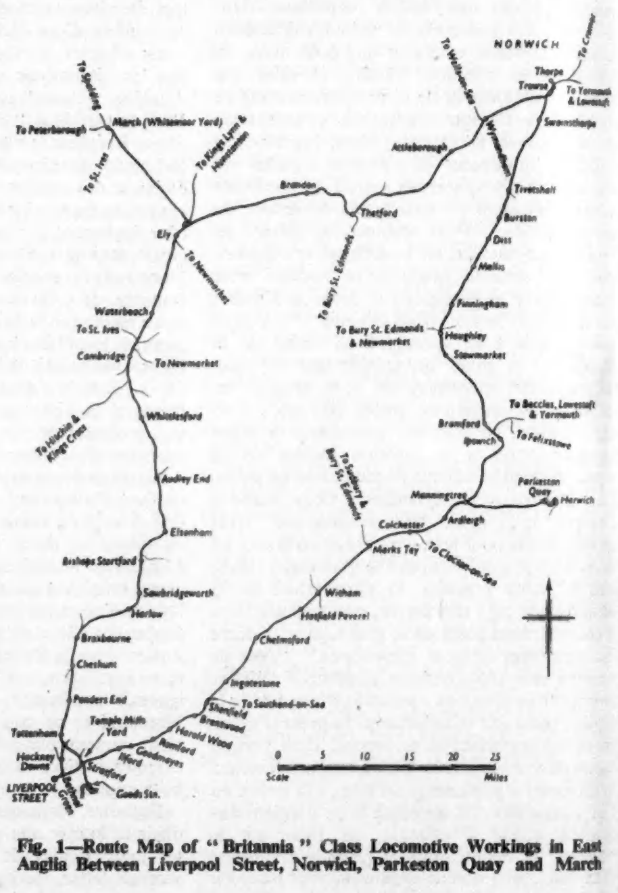

Fig. 1—Route Map of " Britannia " Class Locomotive Workings in East Anglia Between Liverpool Street, Norwich, Parkeston Quay and March

* Previous articles in this series were : No. I, " The L.N.E.R. 2–6–2 ' Green Arrow ' Class," October 11, 1946 ; No. II, " The L.M.S.R. ' Coronation ' Class ' Pacifics ' " December 13 and 20, 1946 ; No. III, " The G.W.R. Oil-Fired 4–6–0s," February 6 and 13, 1948 ; No. IV, " The Mixed Traffic 4–6–0s," November 4 11, 18 and 25, 1949 ; No. V, " The Western Region ' Castle ' Class," April 20 and 27, 1951 ; No. VI, " First Results from the ' Britannias,' " April 4, 1952 ; No. VII, " The Gresley ' Pacifics ' on the East Coast Route," July 18 and 25, 1952 ; No. VIII, " The Thompson and Peppercorn ' Pacifics ' of the Former L.N.E.R.," May 29 and June 5, 1953 ; No. IX " The ' King ' Class 4–6–0s of the former G.W.R., " July 10 and 17, 1953 ; No. X, " Kings Cross-Edinburgh Non-Stop Expresses," July 2 and 9, 1954.

Stratford

Diagram No.	Class of train	Trains worked	Route via	Daily mileage
1	"EP"	Liverpool Street–Norwich	Cambridge	489
	"EP"	Norwich–Liverpool Street	Ipswich	
	"EP"	Liverpool Street–Norwich	Cambridge	
	Class "D" goods	Norwich–Temple Mills	Cambridge	
2	Passenger	4.30 a.m., Liverpool Street–Ipswich	—	376
	Passenger	7.55 a.m., Ipswich–Liverpool Street	—	
	"EP"	11.30 a.m., Liverpool Street–Norwich	Ipswich	
	"EP"	4.45 p.m., Norwich–Liverpool Street	Ipswich	
3	"EP"	5.54 a.m., Liverpool Street–Norwich	Cambridge	474
	"EP"	11.45 a.m., Norwich–Liverpool Street	Ipswich	
	"EP"	5.15 p.m., Liverpool Street–Norwich	Ipswich	
	Class "D" goods	9.52 p.m., Norwich–Goodmayes	Ipswich	
4	"EP"	8.24 a.m., Liverpool Street–Norwich	Cambridge	486
	"EP"	1.45 p.m., Norwich–Liverpool Street	Ipswich	
	"EP"	6.30 p.m., Liverpool Street–Norwich	Ipswich	
	"EP"	10.24 p.m., Norwich–Liverpool Street	Cambridge	
5	"EP"	8.30 a.m., Liverpool Street–Norwich	Ipswich	238
	Passenger	5.12 p.m., Norwich–Liverpool Street	Ipswich	
		NOTE.—Saturdays only: extra trip to Norwich and mileage 477		
6	"EP"	9.30 a.m., Liverpool Street–Norwich	Ipswich	383
	"EP"	2.48 p.m., Norwich–Liverpool Street	Cambridge	
	"EP"	8.30 p.m., Liverpool Street–Ipswich	—	
	"EP"	2.2 a.m., Ipswich–Liverpool Street	—	
7	"EP"	10.30 a.m., Liverpool Street–Norwich	Ipswich	414
	"EP"	3.45 p.m., Norwich–Liverpool Street	Ipswich	
	Class "C" goods	10.5 p.m., Thames Wharf–Whitemoor	Cambridge	
	Class "D" goods	3.45 a.m., Whitemoor–Temple Mills	Cambridge	
8	"EP"	2.55 a.m., Liverpool Street–Norwich	Ipswich	486
	"EP"	7.45 a.m., Norwich–Liverpool Street	Ipswich	
	"EP"	12.24 p.m., Liverpool Street–Norwich	Cambridge	
	"EP"	5.15 p.m., Norwich–Liverpool Street	Cambridge	
9	"EP"	8 p.m., Liverpool Street–Parkeston Quay	—	150
	"EP"	7.42 a.m., Parkeston Quay–Liverpool Street	—	

Norwich

Diagram No.	Class of train	Trains worked	Route via	Daily mileages
1	"EP"	Norwich–Liverpool Street	Cambridge	478
	"EP"	Liverpool Street–Norwich	Ipswich	
	"EP"	Norwich–Liverpool Street	Ipswich	
	"EP"	Liverpool Street–Norwich	Cambridge	
2	"EP"	Norwich–Liverpool Street	Cambridge	256
	"EP"	Liverpool Street–Norwich	Cambridge	
3	"EP"	Norwich–Liverpool Street	Ipswich	460
	"EP"	Liverpool Street–Norwich	Ipswich	
	"EP"	Norwich–Liverpool Street	Ipswich	
	Class "E" goods	Liverpool Street–Norwich	Ipswich	
4	"EP"	Norwich–Liverpool Street	Ipswich	364
	"EP"	Liverpool Street–Norwich	Ipswich	
	Light engine	Norwich–March	—	
	Class "H" goods	March–Norwich	—	
5	"EP"	Norwich–Liverpool Street	Cambridge	375
	"EP"	Liverpool Street–Norwich ("The Broadsman")	Ipswich	
	Class "F" goods	Norwich–Cambridge	—	
	Class "E" goods	Cambridge–Norwich	—	
6	"EP"	Norwich–Liverpool Street	Cambridge	239
	"EP"	Liverpool Street–Norwich	Ipswich	
7	"EP"	Norwich–Liverpool Street	Ipswich	375
	"EP"	Liverpool Street–Norwich	Cambridge	
	Class "E" goods	Norwich–March	—	
	Class "H" goods	March–Norwich	—	

the fact that nowadays engine workings from London do not extend beyond Norwich, is particularly favourable to the double-shifting of locomotives and the making of daily mileages in excess of 400.

In days prior to the first world war the "Norfolk Coast Express" took the avoiding line east of Norwich and made a non-stop run from Liverpool Street to North Walsham, 130 miles; but non-stop running was not resumed between the wars and the water troughs at Tivetshall have since been removed. There is now only one set of troughs, those at Halifax Junction, just on the London side of Ipswich. The "Norfolk Coast Express" was scheduled to pass Trowse, 114 miles, in 134 min from Liverpool Street; this booking was kept by non-superheater 4–4–0 engines with loads up to 370 tons tare. In 1953, on the fastest of my footplate journeys, we passed Trowse in 116 min, inclusive of 5 min standing at Ipswich. The load was 309 tons tare, but there is a great deal more in it than a mere comparison of loads, and of the running averages of 51 and 61·6 m.p.h. The fastest timing of to-day is that of the "Broadsman"—3.30 p.m. down from Liverpool Street, running the 115 miles to Norwich in two hours with a 3 min stop at Ipswich. On this timing the "Britannia" class engines are limited to a nominal maximum load of 300 tons, and on trains that convey heavier loads somewhat slower timings are operated.

It is important to regard the Great Eastern schedules in respect to the speed restrictions imposed. In contrast to some routes in other parts of the country, where the speed limit has been removed altogether, the main line via Ipswich was, at the time of my journeys, restricted as follows:—

Miles from London	Station	Speed limit, m.p.h.
1·1 to 4·0	Bethnal Green-Stratford	50
4·0 to 20·2	Stratford-Shenfield	60
20·2 to 29·7	Shenfield-Chelmsford	70
—	Chelmsford Station	60
29·7 to 35·9	Chelmsford-Hatfield Peverel	70
35·9 to 51·7	Hatfield Peverel-Colchester	80
—	Colchester Station	40
51·7 to 59·5	Colchester-Manningtree	80
—	Manningtree Station	70
59·5 to 68·0	Manningtree-Halifax Junction	80
—	Ipswich Station	Stop
68·7 to 82·9	Ipswich-Haughley	80
—	Haughley Station	65
82·9 to 91·4	Haughley-Mellis	75
91·4 to 112·9	Mellis-Trowse Upper Junction	80

It is no secret that on certain occasions speeds considerably in excess of 80 m.p.h. have been claimed by some observers taking notes from compartments in the trains, particularly north of Mellis. The "Britannia" class engines are, however, not fitted with any form of speed indicator, and with a free-running engine a driver may be forgiven for an excess of some 5 per cent above the limit. When the East Anglian services were being worked by relatively small 4–4–0 and 4–6–0 locomotives the various sharp gradients of the main line, particularly those succeeding the permanent speed restrictions at stations like Chelmsford, Colchester and Ipswich, were a source of considerable hindrance in the making of a fast run; but with locomotives having the tractive power and steaming capacity of the "Britannia" the effect has been to "iron out" the gradients, and even on the fastest bookings there would appear to be still a considerable margin of time in reserve. On the Cambridge line, the timings are not so fast, despite the recent accelerations, but the speed restrictions are more severe. The maximum speed permitted anywhere is 70 m.p.h.

I made six journeys on the footplate, as enumerated in the table overleaf.

Runs 1, 2 and 3 were made with normal mid-week loadings, while 5 and 6 were with trains of over 400 tons on a Saturday. On these latter occasions the timings of 83 min to 85 min for the 68·9 miles between Liverpool Street and Ipswich allow a considerable margin for recovery in case of signal checks and other delays. This was particularly noticeable on Run No. 5, when we reached Ipswich in 85 min, despite 7 min delay on

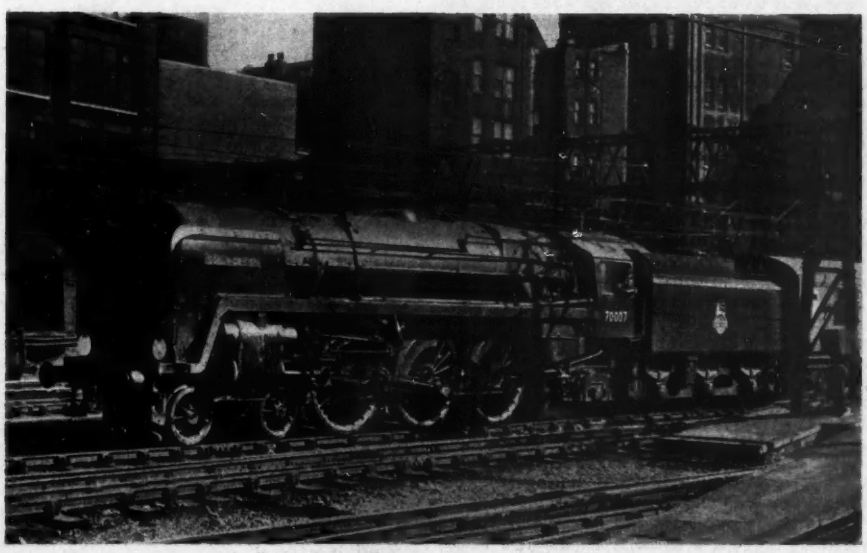

Fig. 2—"B.R.7" Standard 4-6-2, No. 70007, "Cœur de Lion," at Liverpool Street

the road. Run No. 4 was of particular interest, with a partially-braked express goods train at night ; this was in working Stratford duty No. 1, on which the engine had already made a return trip to Norwich on passenger trains, and had come down for the second time on an afternoon express via Cambridge. Furthermore, this was on a Friday evening, and in showing the intensive use made of these locomotives at summer week-ends, I noted engine No. 70010 on the following day at Ipswich working the 9.55 a.m. Norwich to Liverpool Street. As we did not arrive at Temple Mills yard until 11.45 p.m. on the previous evening the engine must have worked straight back to Norwich during the night after following through a " diagram " of 489 miles on the Friday.

Footplate Journeys

Number of run	Engine		Train	
	Number	Name	Time	Route
1	70009	" Alfred the Great "	3.30 p.m.	Liverpool Street-Norwich
2	70030	" William Wordsworth "	8.0 a.m.	Norwich-Liverpool Street
3	70035	" Rudyard Kipling "	12.30 p.m.	Liverpool Street-Norwich
4	70010	" Owen Glendower "	7.20 p.m. Goods	Norwich-Temple Mills
5	70037	" Hereward the Wake "	9.30 a.m.	Liverpool Street-Ipswich
6	70039	" Sir Christopher Wren "	12.41 p.m.	Ipswich-Liverpool Street

(*To be continued*)

Effect of Grinding on the Fatigue Strength of Steels*

By D. N. CLEDWYN-DAVIES†

The paper is a description of an investigation to determine the effects of cylindrical grinding on the fatigue strength of a range of steels : a nickel-chromium-molybdenum alloy steel hardened and tempered to give a nominal ultimate stress of 80 *tons per square inch, the same steel hardened and tempered to give a nominal ultimate stress of* 62 *tons per square inch* (*Vibrac V*30), *a* 0·6 *per cent carbon steel* (45 *tons per square inch*), *and a* 0·1 *per cent carbon steel* (27 *tons per square inch*). *Fatigue tests were carried out in a rotating-beam machine giving uniform bending moment, and the limiting fatigue ratios* (*endurance limit/ nominal ultimate stress*) *of* 0·538, 0·545, 0·420 *and* 0·550 *were determined for turned and longitudinally polished specimens of the Ni-Cr-Mo steel* (80 *tons per square inch*), *Vibrac V*30, 0·6 *per cent carbon and* 0·1 *per cent carbon steels.*

Introduction

It has long been generally accepted that the endurance limit is greatly affected by surface finish. For instance, from Moore and Kommer's results (1921) it appears that 20 per cent of the fatigue strength is lost by having a rough-turned finish, and about 14 per cent lost when the finish is smooth turned, compared with a polished finish. Thomas's work (Thomas, 1923) on the effect of various workshop finishes on a 0·33 per cent carbon steel has also indicated that the rougher the surface, the greater is the loss of fatigue strength. A recent paper by Phillips and Heywood (1951) has shown that even the direction of polishing with a fine-grade emery paper has an effect on the endurance limit of alloy steels. Their tests were carried out on an alloy steel (63 tons per square inch) subjected to reversed direct stress, and the change of direction of polishing from the longitudinal to the circumferential direction caused a reduction of about 15 per cent in the fatigue strength.

There is, moreover, some indication that grinding, as a finishing operation, may not be so good as a casual inspection of a well-ground surface might cause one to expect. In the rotating bending tests carried out by Moore and Kommers (1921) on a 0·49 per cent carbon steel, grinding reduced the endurance limit by about 10 per cent. The work of Thomas (1923) on a 0·33 per cent carbon steel has indicated that a reduction of about 4 per cent in the fatigue strength, due to grinding, could be expected. Experimental work by Bacon (1933) has also shown that the fatigue strength was reduced when a 0·5 to 0·6 per cent carbon steel was ground, and that the amount of reduction depended upon the quality of grinding, fine grinding causing a 2 per cent reduction, while coarse grinding caused a 12½ per cent reduction.

A comprehensive investigation into the stresses and cracking caused by grinding and quenching steels was carried out by Brophy (1930). He showed that all grinding, whether using correct or incorrect grinding procedure, introduced tensile stresses into the surface being ground, and that both grinding and quenching stresses could be of such a magnitude as to cause cracking of the surface layer. Brophy suggested that the surface tensile stresses occurred because, during grinding, the temperature between the wheel and the work being ground was so high that the material immediately beneath the wheel was heated into the austenitic range. The expansion of the small volume beneath the wheel, which could take place only outwardly because of the comparative rigidity of the surroundings, caused a bulge at the surface. In passing over the work the grinding wheel removed the bulge and, provided no cracking had occurred, the quenching of the small heated volume by the adjacent material left the surface being ground in a state of high-tensile stress. Swester's remarks (Swester, 1930) in the discussion of Brophy's paper, are well worthy of note, as he suggested that the use of too high speeds and feeds, a too hard or glazed wheel constituted " abusive grinding." Swester's experience had also shown that distinctly abusive grinding was needed to cause cracking in steels that had been correctly heat-treated.

Almen's work (Almen, 1943) also has shown that grinding produced very serious surface tensile stresses in the skin of the material. Furthermore, he showed that grinding caused hardening of the surface layer and that the residual stress gradient had an extremely high value. The mechanism of producing tensile skin stress was considered by Almen to be analogous to that of the surface tensile stresses produced in brake drums and clutch plates under operating conditions, where the instantaneous temperature in a thin layer was so great that the surface layer was stressed by thermal expansion beyond the yield point in compression. When the source of heat was removed the surface was quenched by the adjacent cool metal and, under thermal contraction, became severely stressed in tension.

Work by Boyer (1948) indicated that even the most careful grinding procedure induced tensile stresses in the surface of the material, and that the fatigue strength of a hardened steel part was lowered by grinding. Furthermore, it was shown that the austenitising temperature had a marked influence on the stress conditions induced by grinding, because of the structural changes that took place owing to heat generation in grinding. It was apparent from his work that the amount of stock removed by grinding also affected the fatigue strength ; the greater the stock removed the bigger the decrease in fatigue strength.

Tarasov attributed the reduction in the endurance limit due to grinding, found by Boyer, to undetected " burning " of the ground surface. Tarasov, in conjunction with Grover (Tarasov and Grover, 1950), therefore, carried out some experimental work on the effects of grinding on the endurance limit of a heat-treated, ball bearing steel. The tests were carried out in reversed plane bending, using flat bars, with control of the severity of grinding by the adjustments of speeds, feeds, and wheel grade. Some rotating bending tests were also carried out, but only with " gently ground " specimens and additional processes. With the flat bars, two grinding severities were investigated : " gentle grinding," representing ideal grinding conditions, and " severe grinding," representing poor grinding conditions without surface cracking. Some of their conclusions are as follows :—

(1) Careful longitudinal grinding of hardened steel specimens, whether flat or round, has no effect on the fatigue strength. (Contrary reports, published and otherwise, are attributed to faulty grinding practice.)

(2) Compared with " gentle " grinding, " severe " grinding reduced the reversed bending-fatigue strength by 20 to 25 per cent.

This investigation seems to be the most recent full-scale attempt to determine the effects of grinding on the fatigue strength from a practical engineering standpoint, and, because of this, the paper of Tarasov and Grover (1950) will be discussed in more detail than the previously mentioned investigations.

A summary of the results is reproduced in Tables I and II, and it can be seen from these tables that the results are most unexpected. It is usual for hardened and tempered alloy steels to exhibit a higher fatigue strength when the surface finish is finer, and this has occurred only in one series of tests. Clearly, however carefully the grinding is carried out, and even though the scratch direction be parallel to the applied stress, it would seem desirable to compare the fatigue strengths of the " gently " ground specimens and those with additional processes, with the fatigue strength of specimens finished in a conventional manner ; for example, by turning and longitudinal polishing. The experimental evidence given by Tarasov and Grover (1950) does not seem to the author to justify the conclusions drawn by them. Consideration of the published and unpublished reports on the effect of grinding upon the fatigue strength leaves ample room for doubt as to whether grinding has any deleterious effect or not.

TABLE I.—*Effect of Grinding and Additional Processes on a Ball-Bearing Type of Steel*

Reversed plane bending tests of flat bars (after Tarasov and Grover, 1950)

Rockwell hardness level	Grinding	Additional processes	Surface finish, micro-inches	Endurance limit, bars per square in	Increase due to additional process, per cent
C59	" Gentle "	None	20	29·0	—
C59	" Gentle "	Hand polish	10	26·3	−10
C45	" Gentle "	None	10	25·8	—
C45	" Gentle "	Electrolytic polish	7	25·8	None

TABLE II—*Effect of Grinding and Hand Polishing on a Ball-Bearing Type of Steel*

Wohler rotating bending test (after Tarasov and Grover, 1950)

Rockwell hardness level	Grinding	Additional processes	Surface finish, micro-inches	Endurance limit, bars per square in	Increase due to additional process, per cent
C59	" Gentle "	None	20	45·6	—
C59	" Gentle "	Hand polish	7	54·5	+19·6
C45	" Gentle "	None	15	62·5	—
C45	" Gentle "	Hand polish	5	56·7	−9·3

Scope of Investigation

The work described in this paper was undertaken primarily as part of a more comprehensive investigation that was being carried out at the engineering laboratories of Bristol University,

* Abstract, Institution of Mechanical Engineers. Written discussion on this paper is invited by the Institution before September 3, 1954.

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where it became necessary to know whether or not grinding had any deleterious effect on the fatigue strength of a particular alloy steel. It was, however, decided to investigate the effect of grinding on the fatigue strength of a number of steels to make the results of more general interest. In normal production work, where both accuracy and surface finish are important, grinding has become a standard finishing operation for many steel parts and, although grinding is used so extensively in industry, little work has been done on its effects on the fatigue strength. This investigation is an attempt to supply some of this information.

Materials and Heat-Treatment

Materials.—The materials used for the investigation were a nickel-chromium-molybdenum alloy steel heat-treated to give a nominal ultimate stress of 80 tons per square inch and 62 tons per square inch; a 0·6 per cent carbon steel and a 0·1 per cent carbon steel. Some preliminary tests were carried out on some Vibrac V30 (62 tons per square inch) already held in stock, the two separate batches of Vibrac V30 being designated "P.T.M." and "A.T.M." The preliminary tests were limited in number owing to the small amount of material then available. The chemical and mechanical properties of the materials are shown in Tables III and IV.

Heat-Treatment.—The material which was hardened and tempered to give a nominal ultimate stress of 80 tons per square inch was first annealed, and the specimens were machined to within small limits of the final dimensions before being hardened at 850 deg. Cent. and quenched at 565 deg. Cent. No further heat-treatment was carried out on these specimens: heat-treatment of other specimens after machining was carried out in a vacuum furnace, the equipment being capable of maintaining a vacuum of 0·001in of mercury while the charge was heated. The heat-treatment records for the various materials before and after machining are shown in Table V.

Table III.—*Chemical Compositions of Materials (Maker's Analysis)*

Material	Carbon	Silicon	Manganese	Sulphur	Phosphorus	Nickel	Chromium	Molybdenum
Vibrac V30 (P.T.M.) 62 tons per square in	0·31	0·22	0·64	0·011	0·016	2·69	0·68	0·57
Vibrac V30 (A.T.M.) 62 tons per square in								
Ni-Cr-Mo (80 tons per square in) ...	0·31	0·16	0·67	0·015	0·013	2·55	0·58	0·58
0·6 per cent carbon Park Gate... ...	0·58	0·16	0·54	0·037	0·033	—	—	—
0·1 per cent carbon Park Gate... ...	0·14	0·09	0·78	0·028	0·026	—	—	—

Table IV.—*Mechanical Properties of Test Materials*

Material	Ni-Cr-Mo (80 tons per square in), hardened 850 deg. Cent., cooled in oil, tempered 565 deg. Cent., cooled in air	Vibrac V30 (P.T.M.), hardened 850 deg. Cent., cooled in oil, tempered 620 deg. Cent., cooled in air	Vibrac V30 (A.T.M.), hardened 850 deg. Cent., cooled in oil, tempered 640 deg. Cent., cooled in air	0·6 per cent carbon as rolled	0·1 per cent carbon as rolled
Upper yield stress, tons per in	—	—	—	28·8*	14·3*
Lower yield stress, tons per in	73*	54	56	21·0*	13·0*
Ultimate stress, tons per in	80*	62	64	44·7*	27·1*
Elongation, per cent	—	24	20	40·0*	21*
Reduction of area, per cent	—	65·8	59·2	43·0*	20*
Izod value	—	84, 86, 90	73, 73, 72	10*	60*
Brinell hardness No.	—	286	293	197*	141*

* Tests carried out at engineering laboratories

Testing Machines

Tensile Testing Machines.—Preliminary fatigue tests on Vibrac V30 (P.T.M.) indicated that there was considerable variation in properties along the length of the bar. Tensile specimens were therefore cut at regular intervals from all the bars used for later tests. The 3-ton autographic recording machine used for these tests was fitted with Robertson type loading shackles.

Tensile specimens (Fig. 1) were also machined from the used ends of the fatigue specimens, and these were tested in a single lever 15-ton tensile machine.

Fatigue Machine.—Fatigue tests were carried out on a rotating uniform bending moment machine, running at a speed of 4000 r.p.m.

Moment Applying Mechanism.—Two ball-bearing races were secured to the tailshaft and held in housings that carried knife-edges at right-angles to the shaft and in the plane containing the shaft centre. Loading of the specimens was carried out by dead weights, the load being transmitted to the knife-edges by a steel tape passing over a pulley.

An equivalent weight of the tailshaft, knife-edge brackets and other fittings was attached to the outer steel tape to eliminate any shear force on the specimen.

Fixing of Specimens.—The specimen was secured in the machine by specially designed spring collets which fitted into the counterbores of the main shaft and tailshaft, and held by two rows of Allen screws at each end.

"Setting-up" of Specimens.—The specimen was brought into alignment with two rows of three equally-spaced Allen screws by means of a dial gauge graduated in 1/10,000 parts of an inch, the specimen being set true within ±0·0001in.

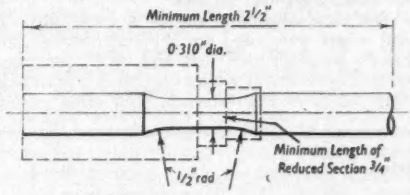
Test Specimens

Fatigue Test Specimens.—The shape of specimen used for these tests is shown in Fig. 2, and it be seen that the specimen had an inch parallel length with transition radii of 3·0in, the specimen diameter being 0·357in. It was necessary to have such a long stressed length because of the importance of reproducing the normal industrial cylindrical grinding procedure.

Tensile Test Specimens.—No tensile homogeneity specimens were made during the preliminary test programme on Vibrac V30 (P.T.M.), but homogeneity tests were made in all further investigations. The size and shape of the specimens used for these tests are shown in Fig. 3. Tensile test (nominal ultimate stress) were carried out on all used fatigue specimens. These specimens were cut from the used ends of the fatigue specimens, and are shown in Fig. 1.

Grinding of Specimens: (a) Grinding Fixture.—Initially the wheel was dressed by moving a diamond around a circular form plate, but light longitudinal polishing with grade 00 emery paper showed the poor surface finish.

From these preliminary tests it was apparent that a new design of grinding wheel profiling fixture was required, and that it should ensure



Machined from broken fatigue specimen

Fig. 1—Specimen for ultimate tensile test

that (1) the diamond cut at a single point, and (2) the diamond traced out the form required at a moderately slow and uniform rate. The fixture consisted of a heavy cast iron base securely fixed to the traverse table of the grinding machine by means of a locating plate and two clamps.

(*b*) *Grinding Specimen Profile.*—When the grinding wheel profile was produced dry the surface of the specimens appeared scratched, as though loose pieces of abrasive were trapped between the wheel and the work being ground. However, when the wheel was thoroughly wetted before profiling and a copious supply of coolant was used during forming, the surface was much improved.

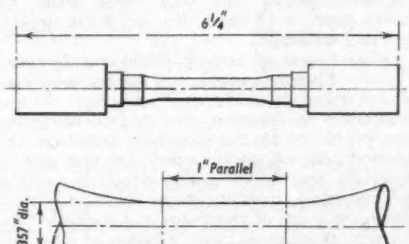


Fig. 2—Uniform bending moment fatigue specimen

The traverse stops were set accurately, and no more than 0·0005in per cut was removed. When the grinding wheel began to cut on the full profile, the automatic traverse was dispensed with, and the machine table was operated by hand. Following this, the automatic traverse was once again set in motion until the wheel cut along the full profile once again. This procedure was carried out until the required diameter of the specimen was reached, the aim being to finish with the wheel cutting along the full profile, while using the automatic traverse.

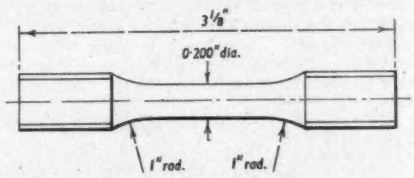


Fig. 3—Tensile specimen—3-ton autographic machine

To ensure that the wheel was cutting a true form and that the surface finish had not deteriorated, the grinding of every other specimen was interrupted, and the surface very slightly longitudinally polished with very fine-grade emery paper. With a little experience it was found that a good estimate of the surface finish and specimen form could be obtained from this inspection.

Table V—*Heat Treatment of Specimens*

Material	Specimens	Heat treatment after rough machining	Heat treatment after preparation of specimen surface
Ni-Cr-Mo (80 tons per square in nominal ultimate stress)	All	Annealed prior to machining then hardened and tempered 850 deg. Cent., cooled in oil 565 deg. Cent., cooled in air	—
Vibrac V30 (P.T.M.)	All	550 deg. Cent., ½-hour soak, cooled in vacuum tube	—
	OG 1, 2, 3 OH 1, 2, 3 OI 1, 2, 3	" " "	550 deg. Cent., ½-hour soak, cooled in vacuum tube
Vibrac V30 (A.T.M.)	All	550 deg. Cent., ½-hour soak, cooled in vacuum tube	—
0·6 per cent carbon	All	800 deg. Cent., ½-hour soak, cooled in vacuum tube	—
0·1 per cent carbon	All	800 deg. Cent., ½-hour soak, cooled in vacuum tube	—

With the preliminary tests the grinding procedure was not exactly the same as with all other specimens ; the procedure of hand feeding at the position of reversal of traverse was not used until there was positive indication of heavy cutting taking place. (Sometimes slight visible burn marks were to be seen at the bottom of the transition radius.) With the careful grinding procedure explained earlier, it was possible to obtain a surface finish of 2–4 micro-inches. Throughout the grinding a copious flow of coolant was used, and no special cleaning apparatus was used for the coolant, although, had such precautions been taken, it would have been possible to obtain even finer finishes.

The same wheel and speeds of work, traverse and wheel were used for all materials investigated, although the 0·6 and 0·1 per cent carbon steels shows a slight tendency to produce burn marks on the transition radii when cutting on the full wheel profile. Particulars of the speeds, feed and wheel, &c., are shown in Table VI, and the grinding was carried out on a standard universal grinding machine.

TABLE VI—*Grinding Speeds and Wheel Used*

Wheel	Norton A60 K.U.
	Speed, ft. per min.
Wheel surface speed	5,300
Work surface speed	15
Traverse speed	5·5

Surface Preparation of Specimen.—All specimens that were not ground were turned and longitudinally polished. The method of polishing was to polish circumferentially the specimens with progressively finer grades of emery paper until grade 0 emery paper was in use ; and then to polish longitudinally, while the specimens were rotating very slowly between centres, with progressively finer grades of paper. Final longitudinal polishing was done with grade 00 emery paper, until there were no visible circumferential scratches.

Measurement of Surface Finish and Specimen Profile.—Specimen profile and surface roughness was checked by a Talysurf recorder. It was impossible to determine the surface roughness and profile of all the specimens tested, so the method adopted was to check the first ground specimen, and then to produce the full batch of ten specimens from the same machine setting. When the batch of specimens was completed the surface roughnesses and profiles of the last ground specimen and two others chosen at random were determined. Whenever a new batch of specimens was ground or the grinding wheel was reformed, Talysurf recordings were always taken.

TABLE VII—*Average Surface Roughness Readings for Fatigue Specimens*

Material	Average surface roughness of specimens, micro-inches (μ)	
	Ground	Turned and longitudinally polished
Ni-Cr-Mo steel (80 tons per square inch)	4·0–5·00	2·0–3·0
Vibrac V30 (P.T.M.)	3·0–4·0	1·0–1·5
Vibrac V30 (A.T.M.)	2·0–3·0	1·5–2·0
0·6 per cent carbon steel... ...	4·5–6·0	2·0–3·0
0·1 per cent carbon steel... ...	4·5–6·0	2·0–3·0

Surface roughness measurements were also made on the turned and longitudinally polished specimens, and the average surface roughness readings (machine averaging meter) for the various specimens tested are shown tabulated in Table VII.

The summary of results of the tests is given in Table VIII.

Discussion of Results

Preliminary test work on the small quantity of Vibrac V30 (designated P.T.M.) available showed a reduction of about 4 per cent in the fatigue strength due to grinding. The fatigue ratio of the turned, and longitudinally polished specimens was not completely determined (true value between 0·530 to 0·540), although the "as-ground" specimens showed a clearly defined limit with a small scatter of results. Two possible reasons for the lowering of the fatigue strength are (1) the precipitation of austenite, which would take place primarily at the grain boundaries, owing to the high contact temperatures, and (2) high surface tensile stresses owing to the drastic quenching of the small heated volume of material immediately in contact with the abrasive wheel by the surrounding metal and coolant. It is difficult to isolate the effect of residual stresses due to quenching and structural changes, as the phase or structural changes are usually accompanied by residual stress. Hence, further tests were carried out on some "as-ground" specimens that had been stress relieved *in vacuo*. The stress-relieving temperature was about 50 deg. Cent. below the tempering temperature, so that had the grinding caused some precipitation of austenite at the surface it would be transformed during the stress relieving. Stress relieving showed no improvement in the fatigue strength of these ground specimens, from which it was concluded that the surface tensile stresses caused by grinding were not of major importance. It is suggested that the reduction in the fatigue strength was owing purely to patches of undetected grinding burn in the lower part of the transition radius, causing, in effect, an inhomogeneity. The question then arises, could these structural inhomogeneities be produced so uniformly that the stress/log *N* curves for the ground specimens would show as little scatter as specimens turned and longitudinally polished ? Remembering how small the reduction is, and yet completely defined, and that the grinding conditions were uniformly controlled, this apparently seems to be so.

When more Vibrac V30 was available, further tests showed no reduction in the fatigue strength due to grinding. The method of producing the large transition radius had in fact been improved, as has been described, yet the possibility of there being a random effect, and a personal effect in grinding, still existed. Some previously ground specimens were therefore reground by an apprentice who had had no previous experience of grinding. In this refinishing operation only the parallel part of the specimens was reground, while using the automatic traverse. In all, about 0·005in was taken off the diameter, and the transition radius was blended into the parallel part by the careful hand operation of the traverse. These specimens also showed no real reduction in the fatigue strength due to grinding, even though the average surface roughness was 10 to 11 micro-inches compared with the earlier grinding of 2·0 to 3·0 micro-inches. This seems a little surprising, because many published works indicate that such alloy steels are sensitive to small variations of surface finish when tested in fatigue.

It was therefore thought desirable to have some specimens ground by other laboratories. Specimens ground in an external laboratory had an average surface roughness of 29 to 30 micro-inches, the grinding having been carried out on a universal grinding machine with hand-operated traverse. The fatigue tests, although few in number, showed very little scatter of results, indicating very uniform grinding, with a definite though not accurately determined reduction in the fatigue strength (approximately 8 to 10 per cent).

To represent commercial grinding technique, four specimens were ground in a machine shop of a local industry and, owing to the difficulty experienced in procuring a fixture to form the required radius on the grinding wheel, the grinding fixture designed by the author was loaned to them. A universal grinding machine with hand operation of the machine controls produced specimens with an average surface roughness of 16 to 17 micro-inches. Fatigue tests showed a large scatter of results presumably due to non-uniformity of grinding, and because of the few tests carried out no definite fatigue strength was determined.

Grinding of the nickel-chromium-molybdenum steel (nominal ultimate stress 80 tons per square inch), Vibrac V30 (A.T.M.), and a 0·6 per cent carbon steel had no deleterious effect upon the fatigue strength. Grinding of a 0·1 per cent carbon steel showed a decrease in the fatigue strength of about 3½ per cent. The cause of this small reduction in the fatigue strength was undoubtedly due to undetected burning of parts of the surface at the lower regions of the transition radius. It was noticed during grinding that there was a greater tendency to cause burn when grinding the 0·1 per cent carbon steel than with any of the other materials. The same work, feed and wheel speeds, and wheels were used for all steels ranging from a nominal ultimate stress of 27 tons per square inch to 80 tons per square inch. The grinding conditions could have been improved for the 0·1 per cent carbon steel by a change in feed and work speed, or wheel. In production work it is certain that a different wheel would have been used for grinding a 0·1 per cent carbon steel and a hardened and tempered alloy steel (80 tons per square inch). Grinding of the 0·1 per cent carbon steel can be termed abusive grinding, but it is clearly shown that distinctly abusive grinding caused by poor grinding practice is needed to cause any appreciable decrease in the fatigue strength.

TABLE VIII—*Summary of Results*

Material	Fatigue ratio		Reduction due to grinding, per cent	Remarks
	Ground specimens	Turned and longitudinally polished		
Ni-Cr-Mo (80 tons per square inch)	0·538	0·538	None	—
Vibrac V30 (P.T.M.)	0·514	0·535 (N.D.)	Approximately 4	—
	0·514		Approximately 4	Stress relieved at 550 deg. Cent.
Vibrac V30 (A.T.M.)	0·543	0·543	None	Ground by apprentice
	0·538		None	—
	0·500 (N.D.)		8–9	Ground by external laboratory
	0·520 (N.D.)		—	Ground by machine shop, local industry
0·6 per cent carbon steel	0·420	0·420	None	—
0·1 per cent carbon steel	0·533	0·550	Approximately 3½	—

Conclusions

(1) The grinding of steels under good grinding conditions has no deleterious effect upon the fatigue strength of the steel.

(2) Poor grinding technique causes a reduction in the fatigue strength of steels.

(3) Stress relieving the ground specimens of Vibrac V30 (P.T.M.), which showed a decrease in the fatigue strength, did not restore the fatigue strength of the ground specimens to that of the virgin material.

(4) The reduction in fatigue strength, due to grinding, was caused by patches of grinding burn on the surface. In grinding fatigue specimens of the type used, this is apt to occur at the lower regions of the transition radius, where cutting is taking place over the full profile of the shaped wheel.

(5) The grinding of steels under good grinding practice produces no more scatter of results than that obtained with turned and hand-polished specimens. In these series of tests the grinding of the Vibrac V30 (A.T.M.) (62 tons per square inch ultimate) showed appreciably less scatter of results than did the turned and hand-polished specimens.

(6) Small differences in ground surface finish (2 to 11 micro-inches) had no apparent effect upon the fatigue strength of a hardened and tempered steel (Vibrac V30 (A.T.M.)).

(7) Careful grinding caused a reduction in the fatigue life of the nickel-chromium-molybdenum steel heat-treated to give an ultimate stress of 80 tons per square inch, although there was no reduction in the fatigue strength of the steel.

General Remarks

A thorough metallurgical investigation to determine the structural changes, the volume of material affected due to grinding burn under controlled grinding conditions with varying grinding severity, and the effect of heat-treatment upon such structural changes should be part of any future programme connected with the effect of grinding severity on the fatigue strength.

George P. Coleman Memorial Bridge in Virginia

(*By Our American Editor*)

No. I

With the completion of the George P. Coleman Memorial Bridge across the York River between Yorktown and Gloucester Point in Virginia, a considerable improvement has been provided in the flow of vehicular north-south traffic along the American East Coast. The 3750ft long bridge includes two 500ft long swing spans placed in tandem which, when open, provide a 450ft wide navigation channel. The structure is supported on light, hollow pier bases which made possible the design of exceptionally tall piers with unusually low bearing pressures. The piers were built with steel caissons fabricated at a shipyard and towed to the bridge site.

MOTORISTS travelling on the major U.S. Route 17 along the Atlantic coast have gained a substantial reduction in travel time due to the replacement of the ferry between Yorktown and Gloucester Point by the George P. Coleman memorial bridge, illustrated in Fig. 2. This tandem swing span structure is said to be the largest of its kind in the world and was constructed by the Virginia Department of Highways at a cost of 9,000,000 dollars. The new toll bridge constitutes an important connection between the upper and lower peninsula of Virginia and has already improved substantially the flow of vehicular traffic from the north to the Norfolk-Hampton Roads area and to connecting southern routes, thus meaning faster travel for motorists from Florida to New York. It is of interest to note that the new crossing means a close link with that section of the United States known as the "cradle of the Republic." In the very shadows of the bridge lie the historic triangle of Yorktown, Jamestown and Williamsburg, the scenes of the beginning and end of the British colonial era in America. At Jamestown, the first permanent English-speaking colony was established. The town served as the capital of the Virginia colony until 1699, when the seat of government was moved to what is now known as Williamsburg. And, not far from the end of the bridge, is the scene of the siege of Yorktown, which ended with the surrender of Lord Cornwallis to Washington and, in turn, brought an end to the War of Independence. The Yorktown-Williamsburg-Jamestown area is now tied together by good roads, all of which form a part of the Colonial National Parkway. Below this area the new bridge connects with the James River bridge system, including three separate bridges which are joined by 11 miles of concrete highway approaches. The total length of the system is 16½ miles, all of it on U.S. Route 17.

As a result of initial negotiations between the U.S. Department of the Interior, the War Department and the State of Virginia, a double-leaf swing span design was chosen for the bridge because of objections to a high-level suspension span or a double-leaf bascule whose high framework would have clashed æsthetically with the colonial atmosphere of the historic city of Yorktown. The two 500ft swing spans provide, when open, a clear 450ft channel with a water depth of 80ft. When the moving spans are closed the vertical clearance is 60ft. Over the river itself there is 2540ft of deck truss construction laid out symmetrically about the central 500ft channel span, as shown in Fig. 1. The flanking spans back from the channel are 390ft, 350ft and 280ft, respectively. Beyond the deck trusses on the north side are eight 90ft approach girder spans. On the south side, six approach girder spans comprise four at 90ft and two at 65ft. The bases for the six river piers are caissons with heights varying up to 110ft. The two central caissons are topped by cylindrical concrete piers on which the swing spans pivot. These piers are 44ft in diameter and 99ft high above the top of the caisson, 40ft of this height being under water. The machinery for operating the swing spans is situated on the bottom chords of the swing spans, directly over the piers, and the electrical equipment is housed within the piers. The other four river piers, which are rectangular in shape, are from 32ft to 44ft in height above the water.

The crossing has a total length of 3750ft between abutments and crosses the 2600ft wide York River between Yorktown on the south bank and Gloucester Point on the north bank. The approach spans of the bridge terminate in abutments situated at the top of a natural slope on the south bank and on a 40ft high artificial embankment on the north side. At the centre of the channel span the roadway attains a height of 115ft above the water by means of 4·5 per cent grades on either side and a vertical curve 1000ft long between them to provide an ample sight distance.

In the conventional design of swing span bridges each end of a span rests on a pier or an abutment, but in the case of the present bridge the forward arms of the two swing spans provide the required 450ft clear width of channel for navigation, so that no pier could be placed at the centre of that channel. Piers could have been placed at the shore ends of each swing span, but this would have resulted in a span length on either side of the channel of only 250ft, which was considered to be too short for economy because of the great depth of the river and the resulting high cost of the piers. Furthermore, the architects and the structural engineers agreed that it would have created a most unpleasant appearance. To increase the length of the spans adjacent to the channel and to permit a curved bottom chord in these spans, the fixed trusses in the adjoining spans are cantilevered by a distance of four panels, or 140ft, beyond the pier and, in the closed position, the shore end of each swing span rests on the

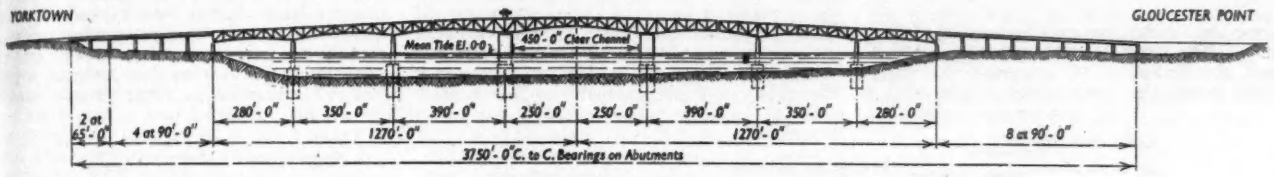


Fig. 1—Elevation of the George P. Coleman Memorial Bridge

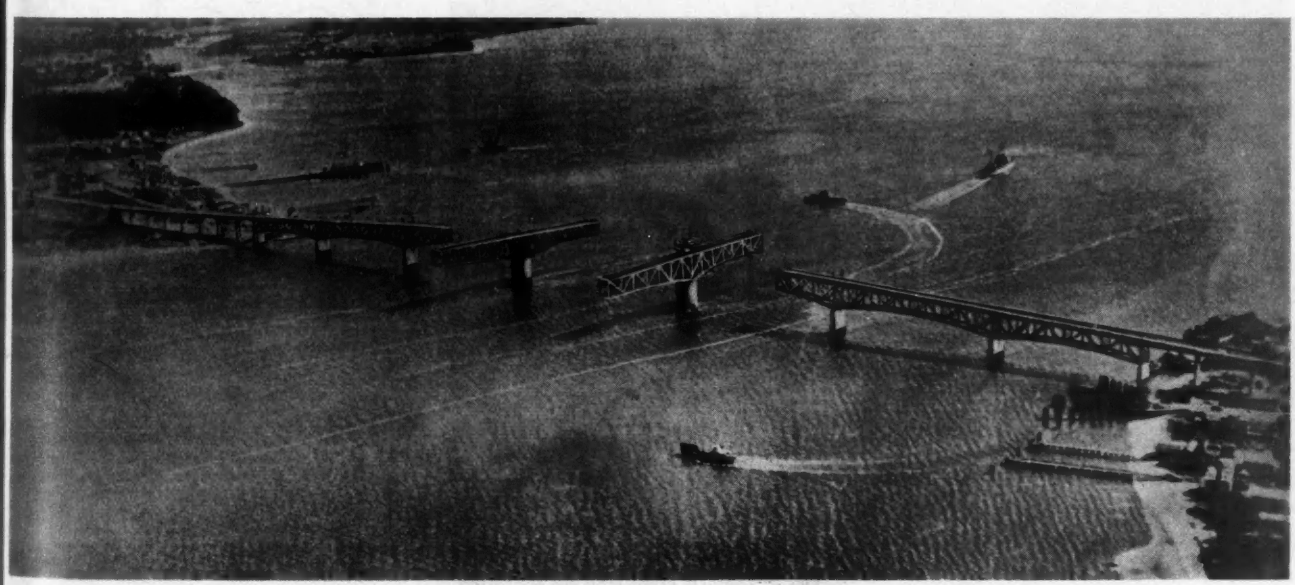


Fig. 2—The George P. Coleman Memorial Bridge in Virginia

end of a cantilever arm. The length of each flanking span is thus increased from 250ft to 390ft. On each side of the channel the next span toward the shore is an anchor span 350ft long, and beyond these is a second cantilever arm 70ft long that supports one end of a 210ft suspended span. Since the shore end of the suspended span rests on a pier situated near the edge of the river, the end truss spans are thus 280ft long. The two-lane roadway is 26ft wide between kerbs 10in high. Each kerb has a width of 2ft 6in, which is sufficient to serve as an emergency walkway.

Bridge Foundations

As indicated in the accompanying table, the water depths at the sites of the six river piers vary from 50ft to 80ft, the average depth being 70ft. One or more borings taken at each site showed that the river bed is of rather soft mud,

Summary of Pier Depths and Boring Data

Pier	Depths in feet			Bottom of base	
	Water	Mud	Silt, sand, and shells	Elevation in feet	Material
3S	75	10	50	−135	Very fine sand and shells
2S	80	30	35	−150	Stiff green clay and shells
1S	80	20	49	−150	Grey clay with shells
1N	72	18	50	−141	Fine grey sand with shells
2N	60	40	41	−141	Silt and shells
3N	50	30	45	−135	Green sand with shells

sometimes containing small quantities of loose sand. The depth of mud varies from 10ft to 40ft, the bottom of the stratum being 85ft to 110ft below the water surface. The mud is generally underlain by sand or silt strata, some of which contain clay and broken shells. The sand is predominantly fine to very fine. Although most of the piers are actually founded on these strata, the borings—some of which were driven to a depth of 200ft below the water surface—showed that the principal material supporting the piers is a medium to stiff clay.

Both the resistances to driving the sample spoon, and the laboratory tests of undisturbed samples obtained from borings, led to the conclusion that the net unit bearing pressures from vertical loads must be limited to 4000 lb per square foot in excess of that resulting from the weight of the existing overburden at the depth of the bottom of the pier base. Since permanent vertical loads exert more influence on pier settlement than horizontal forces which are generally at a maximum for only a short duration, a maximum edge pressure of 7000 lb per square foot was considered permissible for vertical loads in combination with horizontal forces tending to overturn the piers. Under such criteria the depth of penetration of the pier base into the bed of the river became a variable in the design, since in most cases the depths at which the piers are founded exceeded the minimum depths required for lateral stability against horizontal movement. As designed, the bearing pressures, after deducting for the buoyancy of the submerged parts of the pier, do not exceed 8000 lb per square foot for the total direct vertical load. The weight of the overburden above the bottom of the pier base is 4000 lb per square foot ; hence the net differential direct pressure is 4000 lb per square foot for all vertical loads. Horizontal forces resulting from wind loads above water and river currents below water increase the edge pressure by an additional 3600 lb per square foot maximum. From the total bearing pressure it has been considered reasonable to deduct 600 lb per square foot as an allowance for permanent skin friction on the embedded depth of the caisson base. This value is equivalent to an average unit friction of 200 lb per square foot.

To reach a stratum capable of supporting the net bearing load previously described, piers 1S and 2S were sunk to a depth of 150ft below mean tide level. Piers 1N and 2N have been founded at elevation −141ft, and the two piers nearest the shores, 3S and 3N, at a depth of 135ft. Laboratory analyses indicate that even the low pressures produced at these depths may cause slight settlements during the first fifty years of the life of the bridge. If they occur at all, it is believed that they will be small in magnitude, uniform in character, and will create no serious structural or maintenance problems. If settlements should become a nuisance to the next generation, they will find that their predecessors have made it comparatively easy to correct for settlement by jacking up the steel superstructure.

Bridge Piers

An illustration of the problem of limiting the gross bearing pressure to 8000 lb per square foot may be obtained from the fact that the tallest pier is 210ft high and that a column of concrete 1ft square and 210ft high has a bearing pressure of more than 30,000 lb per square foot. Thus the employment of solid piers of conventional stepped and tapered design would not have left much of a margin for supporting the superstructure, which, after all, is the only function of a bridge pier. Therefore the pier bases were designed as hollow, reinforced concrete boxes, having exterior walls 4ft thick. One transverse and two longitudinal interior walls, each 3ft thick, divide each base into six cells and mutually brace one another and the exterior walls. The bases for the two pivot piers support-

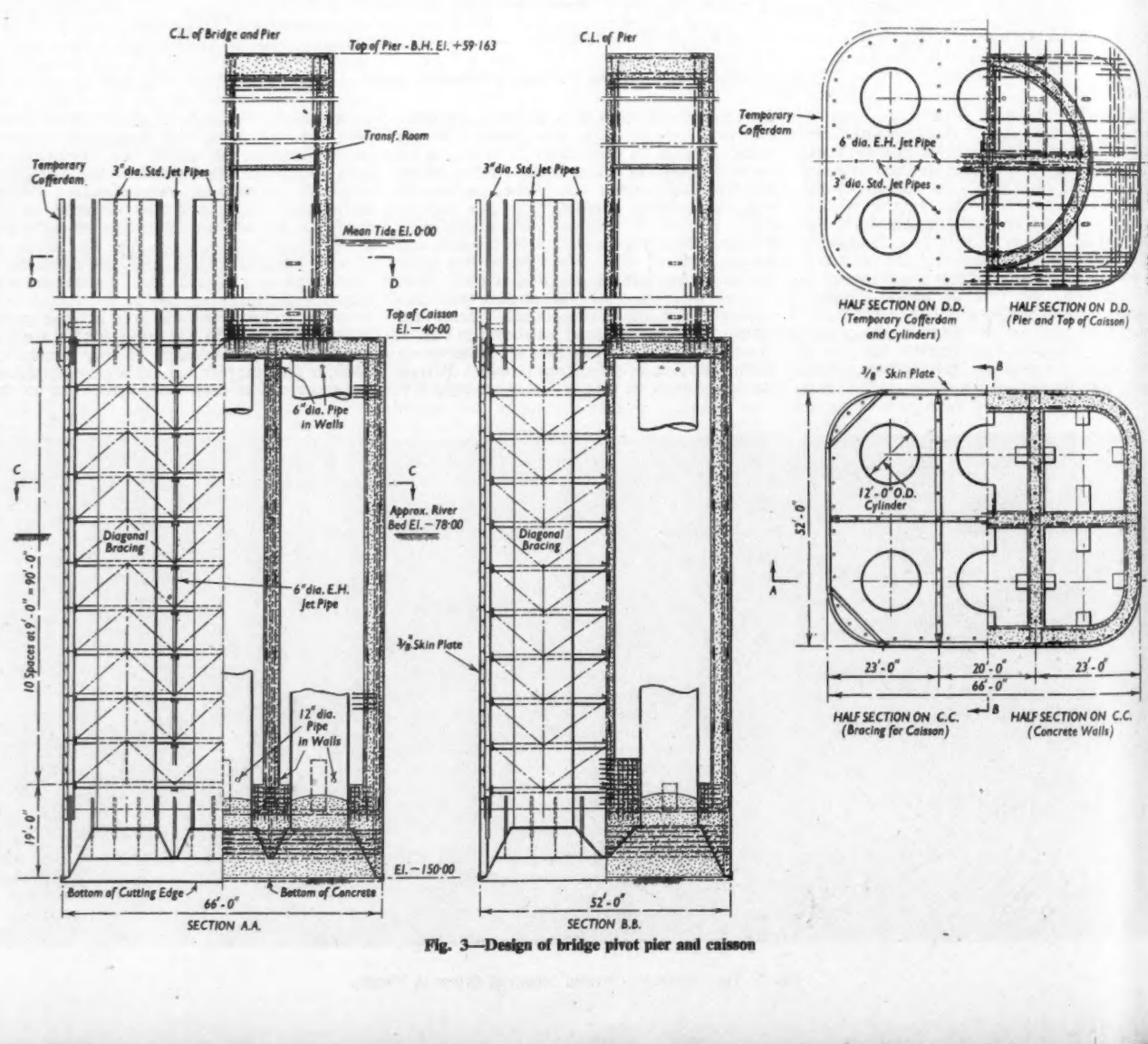


Fig. 3—Design of bridge pivot pier and caisson

ing the swing spans are 66ft by 52ft in plan (Fig. 3), the corners being rounded on a 12ft radius. The other four bases are similar in plan to the pivot pier bases, but are 66ft long by 42ft wide.

The pier bases were designed for construction by the open dredged caisson method. Since the tops of the bases of all the river piers have a plan elevation of −40ft, the highest caisson base was 110ft tall and the shortest 95ft. Follower cofferdams 48ft high, designed by the contractor, were used in the construction of the underwater parts of the pier shafts. After a caisson was sunk to its final depth, the 10ft deep working chamber was filled with concrete deposited under water through tremie tubes in the dredge wells, and the wells were filled with concrete to a height of 4ft. The total depth of seal was 14ft above the cutting edge. The dredge wells were then cut off below the top of the caisson and a 4ft reinforced slab was poured in the dry over the entire top of the caisson. This slab closes in the hollow base and serves, as required, to distribute load from the shaft to the interior and exterior walls of the base. It could not be anticipated in the design that the hollow spaces in the base would remain permanently filled with air. Therefore vent pipes were placed through the top slab to ensure a uniform flooding when the cofferdam was removed. The bearing pressures on the soil beneath the base were computed accordingly.

The shaft of each pivot pier is a hollow cylinder with a shell 3ft thick and two interior cross walls 3ft thick, which are mutually perpendicular. The top 5ft of the shaft is a solid slab reinforced to assist in distributing the load from the centre pivot of the swing span. A part of the interior spaces above river level is used for housing electrical transformers for power and lighting service. Here again vents were provided to ensure equal flooding of the interior spaces below river level and to maintain the same water level inside and outside the shaft. The shafts of the other four river piers, which support the fixed spans, are solid and rectangular in plan. The exterior and interior walls in the bases were designed on the basis of hydrostatic pressure incurred when the caisson is at its final depth with no water in the spaces surrounding the dredge wells. The curved corner sections were designed as unsymmetrical fixed arches assuming points of zero rotation at the intersections with the interior walls. For this temporary condition allowable working stresses of 1350 lb per square inch for concrete and 22,000 lb per square inch for steel were used. The ultimate permanent load, consisting of the pressure of submerged soil, results in much lower stresses. The reinforcement in the cutting edges and bottoms of the cross walls was designed for edge support during sinking, but, because of the depth of water and mud, a substantial part of the concrete walls was constructed before the caisson became non-buoyant ; hence, only a comparatively small percentage of steel is needed to resist bending caused by the edge support.

Bridge Caissons

Some of the caissons were sunk through 80ft of water and, for design purposes, were assumed to reach a depth of 115ft before the soil became sufficiently firm to support them. The necessary buoyancy was provided by steel boxes, within which the reinforced concrete walls were constructed in stages. Since a steel caisson is generally considered to be a piece of construction equipment, it is usually designed by the contractor. Preliminary designs soon indicated, however, that the design and construction of each pier and the design of its caisson were inseparable problems ; hence detailed designs for the caissons were included in the contract drawings. The basic design criteria relating to the completed pier were outlined in the specifications, and the bidders were permitted to submit proposals based on an alternate design for the caissons conforming to those criteria. However, the lowest alternate bid received exceeded the lowest bid based on the design developed by the consulting engineers by more than 1,600,000 dollars.

The magnitude of the work involved in constructing the caissons is indicated by the fact that the 3300 tons of structural steel contained in the six main caissons approximately equals the weight of the structural steel in the superstructure. The consulting engineers gave the contractors the choice of fabricating and launching the caissons in parts and then building them up in 9ft increments as sinking progressed, or of fabricating and launching them full height. The contractor chose the latter method, primarily because the shipyard at Newport News, Virginia, of the Newport News Shipbuilding and Drydock Company offered excellent facilities for complete fabrication, and because the 60-mile channel from the shipyard to the bridge site was deep enough so that the completed caissons could be towed to the site. In the discussion relating to each of the alternative methods it appeared that the advantages of the increment method were that the original draught would be less ; higher concrete lifts could be poured ; placing of concrete over the side of the caissons would be easier ; exposure to squalls would be less risky ; and there would be more opportunity to revise construction methods used in handling the caissons as the work progressed. The advantages of the full-height method appeared to be a saving in time, a saving in space, the pouring of higher lifts, made possible by the use of airtight caps on the dredging wells, and finally a favourable price proposed by the Newport News Shipbuilding and Drydock Company for fabricating the caissons to full height and delivering them to the site.

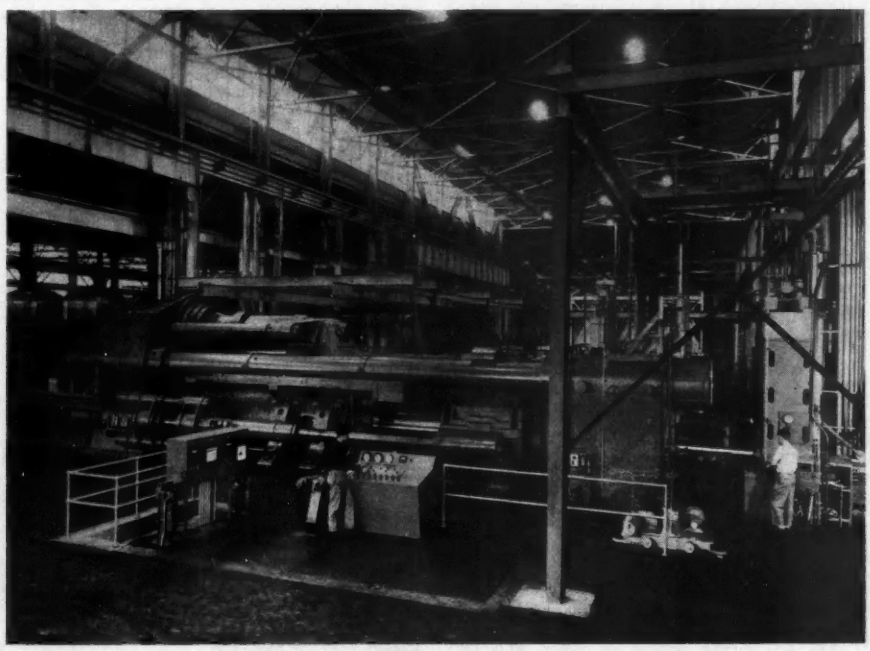
As designed, the caissons were welded throughout and were made of a ⅜in continuous skin plate, reinforced by horizontal steel wales placed at centre distances of 3ft and consisting of continuous 12in structural tees. The wales, in turn, were supported by six vertical " soldier " beams (conforming to the American broad-flange beam section 18WF70) in the planes of the cross rails. The " soldier " beams were supported by 12in broad-flange struts of varying weights at 9ft centres, braced by double-angle diagonals. Since the struts and diagonals are in the planes of the cross walls they became embedded in concrete as the walls were poured in successive lifts. Each level of longitudinal and transverse struts was offset vertically by 6in to eliminate splicing. At the points where the struts crossed an extra heavy pipe, 6in in diameter, extended from top to bottom of the caisson through holes in the webs of the 12in broad-flange struts. The pipes were welded to the struts and served as structural posts. In addition, they were used for jetting during sinking and were extended for this purpose when the follower cofferdam was added.

Because of the relation between the design of the completed pier, the caisson used to build it, and the sequence of construction, stresses and buoyancy conditions were computed for twenty-six separate and consecutive stages of sinking and construction for a representative pier. The results were included in the tendering specifications to acquaint the bidders thoroughly with the scope of the work and the problems involved. The stages were subsequently reviewed and modified to some extent by the contractor chosen. The development of the design followed a rather definite sequence, although there was much " trial-and-error " involved in the process. After the dimensions of the caisson and the concrete wall thicknesses were determined some height-of-wall pour had to be assumed. This height was made such as to permit the placement of a practicable volume of concrete per lift, yet during the buoyant stages of construction up to a 115ft depth—while the caisson was still afloat and its depth below the water surface could not be controlled by dredging—the weight added to the caisson in each lift was limited by the permissible increase in hydrostatic head acting on those parts of the steel caisson that were not effectively reinforced by seasoned concrete. Using a trial design, the draught, freeboard and hydrostatic head were computed for each added increment of concrete. The successive stages that were studied indicated that a head of 23ft above the top of seasoned concrete of the exterior wall occurred frequently and that, after the first 20ft of all the walls had been placed simultaneously, the 23ft head would be considerably exceeded during certain stages, unless the exterior walls were advanced ahead of the interior walls by separate pours. As constructed, the interior walls were 20ft lower than the exterior walls, at times, and the required differential was maintained until the caisson was firmly seated and did not float. Within the range of differential pours the exterior walls were provided with keys and dowels to ensure an effective transfer of stress.

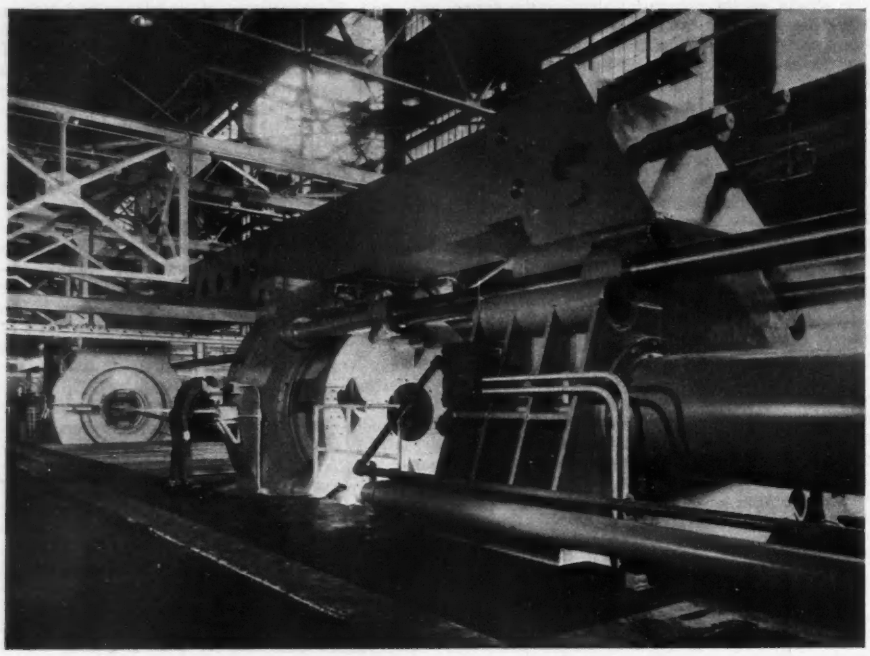
(*To be continued*)

14,000 Ton Extrusion Press

The 14,000-ton Schloemann extrusion press at the Lafayette Works of the Aluminum Company of America, in Indiana, went into full production at the end of May. The machine, which is shown in the accompanying illustration, is believed to be the largest extrusion press in the world and is the first unit of the " Heavy Press Programme " of the U.S. Air Force to go into production. With the installation of this press the company can now offer extrusions weighing



14,000-ton extrusion press at Lafayette, Indiana



The 3,000,000 lb stretcher-straightener at Lafayette, Indiana

as much as 2500 lb per piece, and having a length of as much as 110ft per piece. The size which can be produced in that length has increased from 5·4 lb to 22·7 lb per foot, or from 4·5 square inches in cross-sectional area to 19 square inches. The maximum circumscribing circle diameter for shapes has been increased from a previous 13in to 23in. It may be recalled that this press was being constructed by Schloemann, A.G., of Dusseldorf, and was practically completed at the end of the last war. The U.S. Air Force placed an order with Schloemann for the work to be finished and the press was purchased for installation in the United States. Under the direction of the Aluminum Company of America, the press was subsequently redesigned to meet American production standards, and its total force was increased from 13,200 to 14,000 tons. A sister press of 13,200 tons capacity was taken behind the Iron Curtain in 1945 by the Soviet Government.

The press is a non-piercing unit and comprises three main cylinders arranged on the vertical axis of the machine. In line with the original 13,200-ton capacity of the press, there is an 8000-ton central cylinder and two 2600-ton auxiliary cylinders. The press is of the four-column design, consisting of four 23in diameter main columns, placed on 116in centres, both vertically and horizontally. The main pull-back cylinders are attached to the back ends of the auxiliary cylinders, projecting inside the hollow rams of the cylinders and acting through yokes. A mandrel manipulating cylinder is similarly mounted inside the hollow ram of the main cylinder, with push-back cylinders acting between the main and manipulating cylinder crossheads. The billet size is 29in maximum diameter by about 72in maximum length, requiring a 79in container length. The stroke of the press is only 72in, being thus equal to the maximum billet length. There is no provision for additional stroke, since the billets are charged into the billet container by virtue of shifting the container proper, which is somewhat slower than the conventional method. For hollow extrusions tubular billets must be resorted to. The press structure is unusually compact and requires a length of only 65ft. The press height is 32ft, of which 18ft 6in is above and 13ft 6in below floor level. The press has an overall width of 22ft.

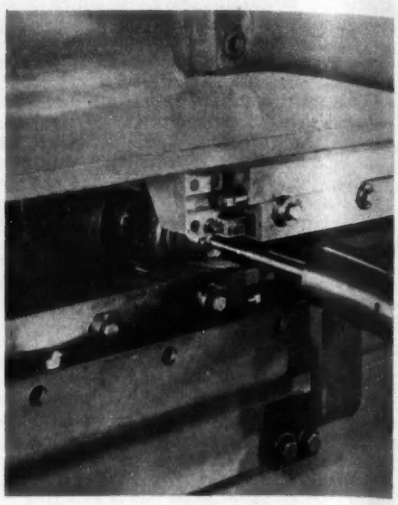
To operate in conjunction with the large extrusion press, the company has designed and installed a 3,000,000 lb stretcher-straightener, which is illustrated at the top of this page. It has an overall length of 180ft and can handle extrusions up to 110ft in length and up to 60 square inches in cross-sectional area. Auxiliary equipment installed at this works includes a number of 60 c/s induction heating furnaces for extrusion billets, a 120ft long horizontal solution treating furnace, and a 120ft long age-hardening furnace.

Spline Rolling Machine

AN interesting machine for the production by cold working of splines, oil grooves, serrations, and other similar shapes on external parts has been developed by the Michigan Tool Company, of Detroit, Michigan. This so-called "Roto-Flo" machine generates splines or similar shapes by means of a cold working rather than a machining process. In the operation of the machine a metal shaft is placed between the forming racks, which are shown in an accompanying illustration, and emerges in a few seconds with the teeth completely formed at any desired position along the shaft. The resulting splines are said to have a high degree of accuracy and an excellent surface finish. Since the metal is displaced and not removed, the blanks are usually machined to the pitch diameter before forming. Tests have indicated that parts produced with rolled splines will withstand higher torsion loads for equivalent shaft sizes than the parts with splines hobbed or shaped from the same material. An important advantage of the process is the fact that teeth can be formed all the way up to a protruding shoulder diameter. Since a recess for tool clearance adjacent to the shoulder is not required with the new method, and the shoulder is not damaged in any way, greater strength and better bearing surfaces are obtained.

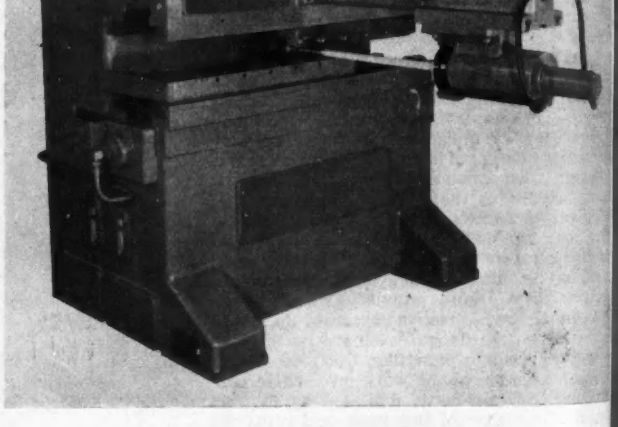
In a pilot production run on the machine, splined shafts of 1¼in diameter and 1¼in length were formed in three seconds. The return stroke, with the machine empty, took two seconds. The parts in question were rolled from S.A.E.1037 steel ranging in hardness up to 41 on the Rockwell "C" scale. The finish obtained was 3 to 6 micro-inches and the accuracy was within 0·0008in variation from part to part over pins.

The basic components of the machine, besides the forming racks, are two slides and an extremely heavy "C"-shaped machine frame. The two slides, which hold the forming racks, are mounted one above the other. The slides are geared together with master racks and a connecting gear. The lower rack is the prime mover and obtains its power from hydraulic cylinders.



Forming racks on "Roto-Flo" machine about to roll a helical spline

The forming racks are adjustable toward the part centre to obtain proper size, and are also adjustable longitudinally to obtain the correct relationship with the part axis. The parts to be formed are supported between centres or by other suitable methods, so that the shaft is rotated by the movement of the forming racks. The racks are designed to press deeper and deeper into the parts as they roll together until full depth is reached, when a few additional turns are made at full depth. The forming racks have been made of a high-carbon, high-chromium steel. An automatic coolant system is provided for cooling the forming racks and splines under mass production conditions. The machine is interlocked to prevent the forming racks from returning until the workpiece has been removed. Furthermore, the working stroke is held up automatically until the part to be splined is properly mounted and the operator's hands are safe.



"Roto-Flo" spline rolling machine

Industrial and Labour Notes

United Kingdom Trade Figures for July

The provisional overseas trade figures for July show that exports from the United Kingdom were valued at £247 million, or more than 10 per cent above the monthly average for the second quarter of the year, and compared with £226 million in the previous month. It should be pointed out, however, that July is a long month with twenty-seven working days, in which exports tend to rise before the summer-season fall. The export figures for July were 5 per cent more than in July of last year, and this compares with an increase of 7 per cent for the first six months of this year over the corresponding period of 1953. Re-exports at £9,300,000 were higher than in any month this year except March.

Imports for July, at £289·8 million, were 4 per cent more than the monthly average in the first half of the year, but continued at about 1 per cent below the level of a year ago. The excess of imports over total exports, including re-exports, was thus reduced in July to £33,500,000. For the first seven months of this year, the average rate of excess of imports over exports was £44,000,000 as compared with £61,500,000 in the same period of 1953.

Figures issued at the same time show that United Kingdom exports to North America in July were valued at £24,100,000, about £500,000 less than the monthly average in the second quarter and nearly 20 per cent below the level of July last year.

Exports to the United States in July, at £12,900,000, were a little higher than the second quarter's average, but 15 per cent less than in July, 1953. Exports to Canada in July amounted to £11,300,000, 7 per cent less than the average in the second quarter and 24 per cent less than in the corresponding month last year.

Engineers' Wages

A resolution that was passed unanimously by the thirty-nine unions represented at the annual conference of the Confederation of Shipbuilding and Engineering Unions last week, called for negotiations to establish a new wages structure for the engineering industry. This resolution also called for new wages scales which would provide substantial pay increases for all grades of workers in the industry.

The main resolution was put forward by Mr. J. Carron, of the Amalgamated Engineering Union, who, in the course of his remarks, said that, after it had been first ensured that the lower-paid workers had sufficient for a decent standard of living, the other grades should receive increases. In the discussion of the resolution Mr. J. Leask, of the Transport and General Workers Union, is reported to have said that after a reasonable minimum had been established it should be recognised that craftsmen's rates were inadequate. By the acceptance of greater differentials between the lowest paid and the most highly skilled workers room would be left for negotiation.

Mr. Leask went on to say that for fifteen years British industry had experienced unparalleled prosperity. Private firms were already running domestic wage structures that set the pattern, and for craftsmen in the Midlands the present national basic rate was only a façade. These workers were being paid more because it was realised that the minimum would fail to attract skilled craftsmen.

The Market in Uruguay

An article in the *Board of Trade Journal* deals with the potential markets in Uruguay for United Kingdom exporters. It states that Uruguay offers a good market for United Kingdom industrial raw materials, vehicles and manufactures, as well as for machinery and capital goods. The market for consumer goods is increasingly restricted, but is still considerable. Substantial quotas have been opened recently, including allocations for raw materials (comprising steel and non-ferrous metals, chemicals, textile yarns and fibres, &c.), builders' hardware and materials, tractors, machinery and lorry chassis. The outlook is promising, especially for tractors and agricultural machinery, fractional h.p. motors, and fencing wire, semi-finished iron and steel products, synthetic yarns, plastic material for processing, radio and electrical components and industrial chemicals, as also replacements and accessories for existing installations in the textile industry. The article states that development projects in Uruguay offer great opportunities. They require, however, first-class representation and careful study of the requirements. As for all Uruguayan Government contracts, price is virtually the deciding factor. Projects include a large new hydro-electric scheme ; extension of the telephone network ; large-scale re-equipment of the railways ; expansion of the State-owned oil refinery in Montevideo; an agricultural development plan involving large purchases of fencing and other farm equipment ; and extensions to the Montevideo water-supply system. It is recommended that British firms should keep in careful touch with the market so as to be ready when tenders are called for, remembering also that all offers have to be submitted through properly accredited agents. In all big Government contracts in recent years, credit terms have been important, the Uruguayans favouring payment facilities of five years and upwards.

Pig Iron and Steel Production

Figures issued by the Iron and Steel Board on pig iron and steel production in this country during July show that steel ingot and casting production during that month averaged 263,100 tons a week, as compared with 371,700 tons a week in June. This fall in output as compared with the previous month is attributed to holidays and to temporary interruptions of production at the works of the Steel Company of Wales, Ltd., as well as to mechanical difficulties at one of the north-east coast steel works.

Pig iron production averaged 211,200 tons a week during the month, and was the highest rate reached in the month of July, although it was less than the weekly average of June, which was 233,200 tons.

The comparative weekly average figures for July last year were 276,600 tons of steel ingots and castings and 202,400 tons of pig iron.

Railway Wage Negotiations

Representatives of the British Transport Commission and the three railway unions spent several hours last Friday in discussions to find a way out of the deadlock which had been reached in the negotiations for a new wage structure for the industry. The discussions proved unsuccessful and a brief joint statement issued after the meeting said that agreement could not be reached. No further joint meeting was arranged. On Tuesday last, however, one of the unions, the A.S.L.E.F., decided to take the dispute through the remaining stages of negotiating machinery.

Fuel Economy in Scotland

Following the transfer of the industrial fuel saving operations in Scotland from the Ministry of Fuel and Power to the Scottish Committee of the National Industrial Fuel Efficiency Service, an intensive fuel saving campaign is to be launched. This campaign is designed to bring about a saving of a million tons of coal a year, and according to Sir Patrick Dollan, the chairman of the committee, specially equipped motor vehicles will be used in the work. Sir Patrick said, in a recent interview, that surveys of a hundred plants in Scotland had already given rise to recommendations for alterations, which would save 160,000 tons of coal a year.

Several branches of industry are represented on the Scottish committee and, in addition to welcoming inquiries from firms requiring technical advice in connection with fuel economy, efforts are to be made to stimulate widespread interest in the subject by all industrial concerns. Sir Patrick stated that the committee intended to provide a service to industry at fees similar to those charged by the Ministry of Fuel during and after the war. The results of such surveys would be regarded as confidential in reporting to the individual concerns.

Shipbuilding Costs and Prospects

Speaking after the launch of the turbine cargo steamer "Bendigo" last week, Sir Murray Stephen, the chairman of Alexander Stephen and Sons, Ltd., referred to the concern amongst the shipbuilders in this country over the prospects of the industry. Sir Murray said that in the first six months of this year orders received had been about equal to one-third of the industry's output and there had been a large number of cancellations of orders. During the first half of last year orders had come in at the rate of about two-thirds the output ; this had not been so alarming, but at one-third, with a lot of cancellations as well, it meant that the balance of orders was a very small trickle indeed. It was quite obvious, of course, that the reason for this was that costs in this country had been rising every year, whereas those in other countries seemed to have been stabilised now for the past year or two.

Sir Murray went on to say that "We are therefore faced with the prospect, at our present level, of being one of the high-cost countries, and what we must do is to strive in every possible way to find methods of reducing costs."

Any further increases in cost or any rise in wages would bring in the long run considerable unemployment. Sir Murray was certain that if the present trend of things—a drying-up of orders with possible further cancellations—continued, the time would not be very far away when the shipbuilding industry of this country would have a very good case to put before the men for a reduction in wages.

Price Index of Basic Materials

The overall price index of British industrial basic materials dropped by 1 per cent in July, and this decrease is attributed mainly to a fall of about 7 per cent in the average prices of raw wool offered for sale during the month. Amongst other prices which fell were zinc (by 3 per cent), lead (by 1·5 per cent), and copper (by 0·3 per cent). The commodities which increased in price included raw rubber (by 6·6 per cent), tin ingots (by 3·9 per cent), and imported softwood (by 0·6 per cent).

During July there was no change in the index for the materials used in the mechanical engineering industries, increased prices for rubber, tin and softwood being offset by reduced prices for hardwood, various non-ferrous metal items and some iron and steel tubes. Similar influences affected the index for electrical machinery materials which fell, but only fractionally, by 0·1 per cent.

The building and civil engineering and house building materials indices both rose slightly, by 0·2 per cent. There were increases in the prices of roofing slates, galvanised cisterns, tanks and cylinders, softwood, plywood, joinery and some types of bricks. A few materials fell in price, including hardwood, lead and zinc.

Well over half the price indices for commodities produced in the United Kingdom showed no change over the month. Among those showing increases were refractory bricks, &c. (up 4·3 per cent), glass containers (up 4·8 per cent), glass, other than containers (up 0·6 per cent), galvanised cisterns, tanks and cylinders (up 6·8 per cent), and domestic hollowware (up 1·0 per cent).

Notes and Memoranda

Rail and Road

EDUCATIONAL TOUR FOR RAILWAY WORKERS.—Fourteen men from British Railways and London Transport who gained the highest marks out of over 1000 employees who took evening classes in permanent way construction and maintenance last winter are going to Holland on a five-day tour to study the methods used on the Dutch Railways. They will be accompanied by the two instructors whose classes achieved the best examination result during the course, which was held at sixty different centres. The classes were arranged to encourage the permanent way staff to increase their knowledge of both the theoretical and practical aspects of their work, and consisted of twenty lectures and two outdoor periods of practical work.

Air and Water

HELICOPTER SERVICES.—It is announced that Silver City Airways, Ltd., has been granted authority by the Ministry of Transport and Civil Aviation to operate the first regular helicopter services in this country. The licence is for ten years, and covers helicopter operations over all of the airline's vehicle air ferry routes—Lympne–Calais, Lympne–Ostend, Ferryfield–Le Touquet, Gatwick–Le Touquet, and Southampton–Cherbourg. It is stated that initially the firm will conduct experimental flights with " Westland S–51 " single-engined helicopters. Next year it will start to fly freight, but passenger helicopter services are not expected to start until larger aircraft are available. It is proposed to supplement the firm's existing car-carrying Bristol " Freighters " and " Super-Freighters " with helicopters as soon as possible.

BULK OIL-CARRYING VESSELS.—Shell-Mex and B.P., Ltd., is in process of augmenting its fleet of estuarial and river craft for service in the Bristol Channel and Severn, and in the Medway, Thames, Humber and Trent. Ten such vessels have been or will be ordered from British shipyards for completion in 1955–56. When commissioned they will be employed in distributing petroleum products from the six United Kingdom refineries of Shell and Anglo-Iranian into the main distribution system of Shell-Mex and B.P., Ltd. The vessels will be diesel-engined and built to Lloyd's requirements. They will be fitted with modern radar equipment in some cases ; vessels so fitted will have telescopic masts of special design. Nine of the new vessels will have the Voith Schneider propeller, making it possible for them to dispense with rudder, stern frame and ordinary steering mechanisms. The company's new 530-ton coaster, now building at Clelands, Wallsend-on-Tyne, will soon be launched, and, with the other ten vessels under construction, will bring the Shell-Mex and B.P. fleet of coastal, estuarial, bunkering and river craft to a total of forty-seven.

Miscellanea

ALUMINIUM IN BUILDING.—The papers and the discussions and authors' replies of the symposium on aluminium in building, held in London last June, have now been published in a single volume, price 4s., by the Aluminium Development Association, 33, Grosvenor Street, London, W.1.

OBITUARY.—We regret to announce the death, on August 2nd, of Mr. W. J. Orange, general manager of the English Electric Company, Ltd., for India. William Orange was born on May 12, 1901. He was apprenticed with the Lancashire Dynamo and Crypto, Ltd., and served them for seventeen years, finally as manager for India and Burma. He joined the English Electric Company, Ltd., in December, 1935, as general manager for India.

BOLD POWER STATION.—The British Electricity Authority has received the consent of the Minister of Fuel and Power to the building of the second half of Bold power station. The authorisation covers the installation of three 60MW generating sets, each served by a boiler with an evaporative steam capacity of 550,000 lb an hour, and the building of three cooling towers, each having a capacity of 2,250,000 gallons of water an hour. When completed, the station will have a total installed capacity of 300MW.

INTERNATIONAL BUILDING RESEARCH BULLETIN.—The International Council for Building Research Studies and Documentation has published the first issues of a periodical bulletin, which is intended to promote international, and especially European, co-operation in building research. The bulletins are published with three columns giving the text in English, French and German. The administration of the *C.I.B. Bulletin*, as it is called, has the following address : c.o. Bouwcentrum, 75, Diergaardesingel, Rotterdam, The Netherlands.

OPENCAST COAL IN YORKSHIRE.—An agreement limiting opencast coal working within the parish of Wentworth, Yorkshire, has been reached by the Ministers concerned and the local authorities. In view of the urgent national need of coal from opencast sources, some further working must take place in the parish, but strict limitations on the area of working are being imposed, partly in the interest of agriculture and partly to protect the amenities and appearance of the mansion of Wentworth Woodhouse, and its woodlands, and of the parish in general.

AGRICULTURAL ENGINEERING.—Scholarships have recently been awarded to two candidates for the National Diploma in Agricultural Engineering, to be applied towards the cost of the year of study leading to the final examination. The Council of the Institution of British Agricultural Engineers also states that it is indebted to the directors of the Temple Press, Ltd., for the continued gift of the " Farm Mechanization " Scholarship. In addition, the council announces the gift of a new scholarship, to the value of £250, offered this year for the first time by Pest Control, Ltd.

AMERICAN NUCLEAR POWER STATION.—The scientific correspondent of the *Financial Times* reports that the first nuclear power plant in the United States is to be built, just over 20 miles from Pittsburgh, at Shippingport, Pa., beside the Ohio River. The plant is being built by the Duquesne Light Company of Pittsburgh and the Westinghouse Electric Corporation. The site, electric power plant and 5,000,000 dollars towards the cost of the reactor are being provided by Duquesne, and the reactor and cooling circuit leading to the heat transfer unit are being designed and built by Westinghouse.

A CORROSION ADVICE BUREAU.—The British Iron and Steel Research Association has formed a corrosion advice bureau in order to deal adequately with the numerous inquiries that are received for advice on the prevention of corrosion of ferrous metals. The Bureau will be situated at 140, Battersea Park Road, London, S.W.11. We are informed that Dr. J. C. Hudson has been appointed head of the bureau and Mr. E. E. White secretary, whilst Dr. W. H. J. Vernon has been engaged as consultant. The services of the bureau, which will normally be free to members of the association, will also be available to others on a fee paying basis depending on the extent of the investigations required.

THE JUBILEE OF THE THERMIONIC VALVE.—The Council of the Institution of Electrical Engineers has arranged for the jubilee of the thermionic valve to be celebrated by the Institution on November 16, 1954, fifty years exactly from the date of the application by Sir Ambrose Fleming for the British patent for his thermionic valve. The proceedings will be opened by the Lord President of the Council, the Marquess of Salisbury, and three lectures will be delivered, one each by Sir Edward Appleton, Professor G. W. O. Howe and Dr. J. Thomson, dealing with valves from the earliest developments to the present day. An exhibition of historical apparatus will be held at the Institution building in London, in association with the celebration.

PLASTIC TUBING.—Thermoplastic tubing for water, gases, compressed air and chemical solutions is being made by the Marley Tile Company, Ltd. It is unaffected by acids or alkalis, or by any of the chemicals commonly used in the building and food industries and in agriculture. The tubing is a good electrical and thermal insulator ; it softens under heat, which makes it unsuitable for hot liquids but, on the other hand, simplifies jointing and manipulation. Owing to its resistance it is not easily damaged by wheeled traffic, and is quite immune to frost. The " normal " range is from ¼in to 2in bore, and may be used for 135 lb to 65 lb per square inch, while the " heavy " range, from ¼in to 1in bore, is suitable for 340 lb to 115 lb per square inch.

OIL PRODUCTION.—According to *The Journal of Commerce*, British and associated Dutch oil companies last year produced a record total of 103,840,000 metric tons of oil. This compared with 96,190,000 tons in 1952, and exceeded by some 5,000,000 tons the previous highest total, achieved in 1950 when over 32,000,000 tons came from the Persian oilfields. Of the total production last year, Kuwait supplied 21,650,000 tons and Iraq 14,580,000 tons out of a total of some 40,000,000 tons of oil produced by British and Dutch interests in the Middle East. The next most important source of supply was Latin America, with just under 35,000,000 tons, of which Venezuela supplied 28,190,000 tons. As in other years, the principal oil producers were U.S. companies, which were responsible for 477,330,000 tons out of a world total output of 677,600,000 tons.

WELDING OF STAINLESS STEEL.—A booklet on the metal-arc welding of stainless steels is being published by Rockweld, Ltd., Commerce Way, Croydon, Surrey. For the manufacture of many items for the chemical and process industries, welding is the method of choice. A great number of the available stainless alloys can be welded successfully, even where the conditions of subsequent service are severe, provided the correct procedures are followed. In this connection, a knowledge of the metallurgical principles involved is essential. The present booklet aims at making this knowledge available in a concise form, and at bridging the gap between theory and practice. A description of the main groups of stainless steels is followed by a discussion of the principal welding faults, the selection of electrodes and coatings, welding techniques and notes on metallography.

ALUMINIUM DEVELOPMENT ASSOCIATION TO JOIN THE C.I.D.A.—At a recent meeting of the council of the Aluminium Development Association it was decided that an invitation should be accepted to join the Centre International de Developpement de l'Aluminium. It may be recalled that the C.I.D.A. was set up some three years ago at the suggestion of the O.E.E.C., and it is constituted of five countries at present, namely France, Italy, Switzerland, Germany and Austria. Its aim is to further the future development of aluminium by discussing problems of common interest among the participating organisations. The secretariat and governing committee of C.I.D.A. is in Paris, at the offices of l'Aluminium Français. Its work has been carried forward through five committees established in 1951, and concerned with architecture, transport, chemical applications, electrical engineering and publicity.

POWELL DUFFRYN TECHNICAL SERVICES FOR KOREA.—By agreement with the United Nations Korean Reconstruction Agency—an instrument of the United Nations—Powell Duffryn, Ltd., announces that its technical services company has been appointed to provide advisory teams to assist with the rehabilitation of the coal mining industry as part of UNKRA's extensive rehabilitation programme in the republic of Korea. The coal mines are controlled by the Dai Han Coal Corporation, which is a Government-owned corporation. We understand that this contract was secured at Seoul in the face of strong international competition and is expected to take two years or more to complete. It will involve the full-time employment of not less than twelve technical specialists from Britain in the various phases of coal mining and ancillary operations. The duties will include long-term planning and advice to the Dai Han Coal Corporation, but will not include Powell Duffryn ownership of, or investment in, the corporation's properties.

Contracts

A CONTRACT has been secured by the Moxey Conveyor and Transporter Company, Ltd., of Augustus Road, Birmingham, for the ore-handling plant at the Cardiff works of the Guest Keen Iron and Steel Company, Ltd. The consulting engineers for this scheme are the International Construction Company, Ltd., of London. The contract is valued at approximately £1,250,000 It comprises the handling of iron ore at the rate of 1500 tons per hour from dockside cranes to the main storage bunkers, from where it will be conveyed to the crushing plant and to a stockyard. After reclaiming from stock the ore will be conveyed to a screening station and finally to the blast-furnace bunkers or stockyard. The plant which also includes the conveying, crushing and screening of incoming limestone, basic slag, and coke, will have a total length of belt conveyors of approximately 2 miles. The Moxey Conveyor and Transporter Company, Ltd., is associated with Clarke Chapman and Co., Ltd., of Gateshead.

Personal and Business

MR. G. E. RATCLIFFE has joined the Wallace Attwood Company as a consultant.

MR. F. W. WHITING has been appointed the Lancashire Dynamo group branch manager for the Nottingham area.

HILLS (WEST BROMWICH), Ltd., has moved its London offices to Chapone Place, 22, Dean Street, London, W.1 (telephone : Gerrard 0526-9).

THE NATIONAL COAL BOARD has appointed Mr. A. Walsh to be director-general of labour relations in place of Mr. Iestyn Williams, who retired last month.

MR. A. C. VIVIAN, project manager for the Anglo-Iranian Oil Company's Llandarcy refinery, retired at the end of last month after thirty years' service with the company.

THE B.B.C. announces the appointment of Mr. E. P. B. Metcalfe as engineer-in-charge of the new television transmitting station under construction at Rowridge, Isle of Wight.

A. G. WILD AND CO., Ltd., of Sheffield, has opened a new London office at 7, Victoria Street, S.W.1 (telephone : Abbey 6761), under the management of Mr. B. G. V. Forman.

THE MINISTER OF TRANSPORT AND CIVIL AVIATION, Mr. J. A. Boyd-Carpenter, has appointed Mr. O. F. Gingell and Mr. S. M. A. Banister to be his joint principal private secretaries.

SIR JOHN GREAVES has decided to relinquish his position as managing director of Davey, Paxman and Co., Ltd. Mr. G. W. Bone has been appointed to succeed Sir John as managing director.

SIR GEORGE E. BAILEY has resigned the chairmanship of Associated Electrical Industries, Ltd., and the Rt. Hon. Oliver Lyttelton has been elected a director and chairman of the board. Sir George Bailey continues to be a director.

SAUNDERS-ROE (ANGLESEY), Ltd., announces that Mr. W. H. Dann, has been appointed to the board of directors of the company. Mr. Dann joined the company in 1944 as chief technician, and in 1946 he was appointed chief designer.

MR. ROBERT ATKINSON has been appointed to the board of directors of the Hamworthy Engineering Company, Ltd., and British Combustion Equipment, Ltd. H. A. Cheetham has been appointed chief engineer of British Combustion Equipment, Ltd.

A.P.V.-PARAMOUNT, Ltd., announces that Mr. J. F. B. Jackson is to join its board as director in charge of the new foundries at Crawley, Sussex. Mr. Jackson has relinquished his position as director of the British Steel Castings Research Association in order to take up this new appointment.

WINSTON ELECTRONICS, Ltd., Hampton Hill, Middlesex, has discontinued its use of the trade name " Voltastat," which has a similarity to another electrical manufacturer's trade name. Instead, " Constavolt " will be used when the stabilised voltage control equipment is designed for battery charging, &c., and " Magnetro " when used for rectification, or as a battery eliminator.

British Patent Specifications

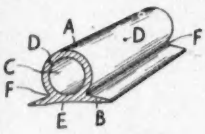
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, price 1s. 6d. each.

SPRAYERS

712,084. October 27, 1952.—HOSE FOR CONVEYING AND SPRAYING LIQUIDS, Josef Müsch and Co., G.m.b.H., 166, Bernhardstrasse, Cologne-Bayenthal, Germany.

The invention relates to a hose which can be used for conveying and spraying liquids, for watering fields, gardens, greenhouses, coal dumps, or the like. The hose may consist of rubber, synthetic rubber or of a thermo-plastic synthetic material, such as plasticised polyvinyl chloride. As the drawing clearly shows, the hose comprises a tubular hollow part *A* and a flange or base part *B*. The tubular part has a longitudinal passage *C* and is formed with perforations *D* which extend substantially radially to its longitudinal axis. The perforations may be distributed over the entire length of the hose or over only a part of its length. In the constructional example illustrated in the drawing, the openings are directed upwardly in oblique directions. The water conveyed in the passage *C* leaves it in the form of fine jets directed obliquely upwards towards both sides. The base part *B* is supported on the ground by its lower surface *E* and is sufficiently wide to maintain the hose in the required position on the ground regardless of the internal excess pressure and any stresses in the material, so that the water jets issuing from the openings *D* will be deflected upwardly in the required inclined direction. The base part consists of the same material as the tube and therefore may be manufactured in one operation with the tube when the hose is made from a plastic material such as a thermo-plastic synthetic resin. Because of the constrictions *F* between the tubular section *A* and the base section *B*, the amount of material used is reduced to a minimum.—*July* 14, 1954.



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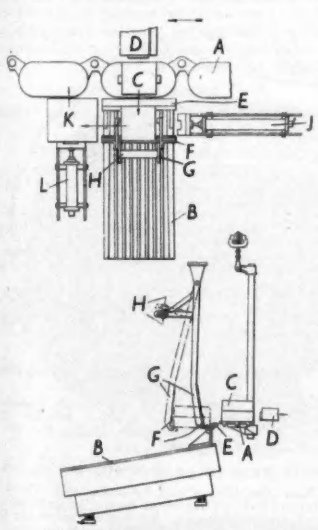
METALLURGY

712,371. June 17, 1952.—SHAKEOUT ARRANGEMENTS FOR FOUNDRY MOULDING CONVEYORS, The Ford Motor Company, Ltd., 88, Regent Street, London, W.1. (*Inventor: John William Leek.*)

The invention consists of a shakeout arrangement for foundry moulding conveyors on which flasks or moulds of various sizes may be accommodated. The moving rail may be supported on a swinging arm. As will be seen from the drawing, a conveyor *A* passes a vibrator or vibrating screen *B* and flasks or moulds *C* on the conveyor are in turn pushed automatically on to the vibrator by means of a pusher *D*. The vibrator has secured to it an attachment *E* in the form of a fixed guide rail, over which the flask slides when the pusher operates. The forward end of the flask then engages a moving guide rail *F* secured to the bottom of a swinging or pendulum arm *G* having



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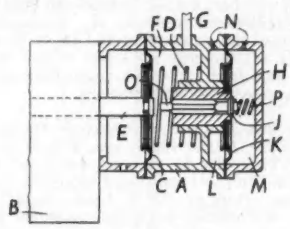
counterbalance weight *H*, or other mechanical rail controlling device, on the side remote from the pusher so that the arm is sufficiently inclined from the vertical to bring the guide rail on it adjacent to the fixed guide rail. Further movement of the pusher then removes the flask from the conveyor and the rear end of the flask drops down on to the fixed guide rail on the vibrator and is thus held between the fixed guide rail and the moving guide rail which has swung out on the end of the pendulum arm to the necessary extent. When the "shakeout" has been completed on the vibrator a further pusher *J* pushes the empty mould along between the guide and moving rails on to a receiving platform *K* and the pendulum arm swings back to close the guide rails together ready to receive the next mould. From the receiving platform the empty mould is returned to the conveyor by means of a further pusher *L*.—*July* 21, 1954.

INTERNAL COMBUSTION ENGINES

712,364. May 1, 1952.—CONTROLS FOR FUEL INJECTION PUMPS, C.A.V., Ltd., Warple Way, Acton, London, W.3. (*Inventor: Wilfrid Edward Walter Nicolls.*)

The object of the invention is to provide an improved control means to ensure stability of action when the engine is running at an idling speed or at high speed under a light load. Referring to the drawing, a hollow body *A* is mounted on the pump *B*. The open end of the body is closed by a flexible loaded diaphragm *C* loaded by a spring *D* and attached to one end of a slidable bar *E* serving to regulate the pump output. The body forms a chamber *F*, which is connected by a pipe *G* to a venturi throat in the air intake manifold at the engine side of the throttle valve in the manifold. At the other end of the chamber is an air bleed valve. This comprises a seating member *H* which is slidable in a bore in the body and has formed in it an axial bore which at the end remote from the diaphragm forms an annular seating for the head of a closure member *J*. The



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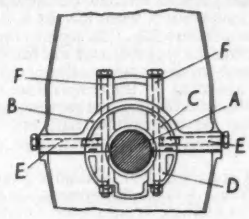
seating member is attached to a second diaphragm *K* which divides another chamber in the body into two compartments *L* and *M*, one of which *M* contains the head of the closure member. These compartments are both open to the atmosphere through restricted orifices *N*. The stem *O* of the closure member extends into the chamber *F* so that it can be moved to its open position by and after a predetermined movement has been given to the diaphragm *C*. The closure member is normally held in its closed position by a spring *P*, which serves also to press the diaphragm *K* or a collar on the seating member into contact with an adjacent face on the body. When the diaphragm *C* is moved to the right the corresponding movement of the control bar *E* effects a reduction of the pump output, a sufficient movement of the diaphragm *E* also imparts an opening movement to the closure member *J*. But the latter movement only occurs when the drop of pressure in the chamber *F* of the body is that corresponding to an idling speed of the engine, or a high speed under light load. When the closure member is opened it admits a restricted inflow of air to the chamber for stabilising the diaphragm *C* to minimise or prevent pulsation of the diaphragm. This inflow is accompanied by a drop of air pressure in the compartment *M* from which air flows into the valve, and the then preponderating air pressure in the compartment *L*, acting on the diaphragm *K*, imparts a follow-up movement to the seating member for automatically restricting the air inflow to the amount required for enabling an optimum stabilising action to be obtained.—*July* 21, 1954.

712,307. July 15, 1952.—CRANKSHAFT BEARINGS WITH CYLINDERS ARRANGED IN-LINE, Bayerische Motoren Werke Aktiengesellschaft, Lerchenauerstrasse 76, Munich 13, Germany.

As the drawing shows, the crankshaft *A* is mounted in the two-part bearer which receives the plain bearing liners and which has practically the same heat expansion coefficient as the crankshaft itself. One of the main bearings, the middle one in a multi-cylinder in-line engine, is constructed as an axially locating bearing, whereas in all the other bearings the crank journals are longitudinally slidable, in order to allow for the difference in thermal expansion in the axial direction between the crankshaft *A* and the light metal case *B*. The top part of the two-part bearer is indicated at *C* and the lower half at *D*. Horizontal forces perpendicular to the longitudinal axis of the crankshaft are taken by transverse bolts *E*, which are fitted in the upper bearer part *C* to hold it tightly to the case *B*. Vertical components are taken by the anchor bolts *F*, which pass through the cam one on each side of the main bearing and firmly secure the bottom part *D* of the bearer to the case by means of the nuts, so that neither the transverse bolts nor the anchor bolts are subjected to any appreciable bending stress. The upper part of the bearing body can, if desired, also be fixed in the case by means of dowels or locating



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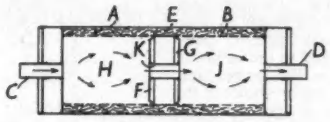
pins. This method of securing the parts of the bearer in the crankcase in accordance with the invention affords a particularly rigid construction of the crankcase, which is of special advantage with divided crankcases. The application of the invention to a barrel-type crankcase of light metal makes possible the advantageous pre-assembly of the two-part bearing bodies *C* and *D* on the crankshaft, and after the introduction of the pre-assembled crankshaft into the crankcase the transverse bolts *E* and the vertical tension anchor bolts *F* can be screwed up from the side and from below.—*July* 21, 1954.

712,134. December 3, 1951.—EXHAUST SILENCERS, Roger De Pauw, 30, Rue Darwin, Brussels, Belgium, and Fred Burgess, 311, Avenue Moliere, Uccle-Brussels, Belgium.

As the drawing shows, the exhaust silencer consists of a cylindrical jacket *A*, within which there is coaxially arranged a wall *B* of a latticework of metal



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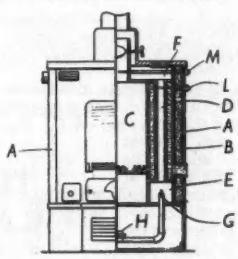
strips, metal gauze or expanded metal. The end walls are welded to covers, to which are connected inlet and exhaust tubes *C* and *D*. Between the jacket and the end walls is a space *E*, which is filled by a mass of soundproofing material, such as glass fibres or glass wool. Two discs *F* and *G* welded to the wall provide a double partition and form two chambers *H* and *J*. The two discs are connected by a tubular portion *K* in order to connect the expansion chambers. As shown by the arrows, exhaust gases enter into the silencer through the tube *C* and pass through the tube *K* into the second chamber *J* and through the tube *D* to the atmosphere. A modified design is also shown in the specification.—*July* 21, 1954.

STEAM GENERATORS

712,186. May 17, 1951.—TWO FUEL BOILERS, The North Eastern Gas Board, Bridge Street, Leeds, 2. (*Inventors: Roger Snowdon Edwards, Arthur Higgs and Robert Henry Anderson.*)

The invention relates to a two fuel boiler capable of using gas and solid fuel. Referring to the drawing,



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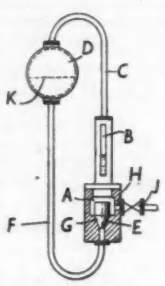
the boiler comprises an outer casing *A* which surrounds on three sides the heat insulating material. The water chamber *B* surrounds the solid fuel combustion chamber *C* having the usual firebars and flue outlet. Flueways *D* are provided in the water jacket from a gas burner chamber *E* below a side part or parts of the water jacket to an upper chamber *F* which connects with the flue pipe. Within the chamber there is provided a gas burner *G*, which is fed with gas by way of a pipe or pipes from a control valve *H* beneath the ashpit in a chamber which has an air entry. A venturi draught baffler is incorporated in the boiler to ensure correct combustion and draught conditions on the gas burners. The automatic controls consist of water temperature limit thermostat *L* and a further thermostat *M* having an insulated sleeve where it passes through the gas

combustion chamber flue projecting into the flue of the solid fuel combustion chamber. The two thermostats are so connected that when the flue gas temperature and the output from the solid fuel fire fall below a certain predetermined level, the gas is turned on to the burners and automatically ignited from permanent pilot lights. The gas continues to burn until the water in the flow circuit attains a predetermined temperature, when the gas is cut off until the water temperature falls. As soon as the solid fuel fire is re-ignited or recovers and the thermal output rises, the supply of gas is automatically cut off by the thermostat operating on the temperature of the flue gases from the solid fuel fire and remains extinguished until the flue gas temperature falls below the predetermined level.—*July* 21, 1954.

712,249. August 13, 1951.—REMOTE LIQUID LEVEL INDICATORS, Vickers-Armstrongs, Ltd., Vickers House, Broadway, Westminster, London, S.W.1. (*Inventor : George Wood.*)

Referring to the drawing, the remote liquid level indicator, shown below a water drum, comprises a chamber *A* opening at its upper end into a gauge tube *B*. The upper end of the gauge tube is connected by a pipe *C* to the upper side of the water drum *D*. The chamber *A* has a frustro-conical port *E*, which is connected by a pipe *F* to the lower side of the water drum. In the port is a valve *G*, the weight of which tends to cause it to seat upon the port *E*. The chamber *A* has also a port *H*, which allows water to leak off, either through an orifice plate or a cock *J*. The water level in the drum is indicated by the broken line *K*. The lower side of the valve *G* has imposed on it a pressure equal to the head of water between the water level *K* and the location of the underside of the valve. On the upper side of the valve *G* is an oppositely directed pressure equal to the height of water in the gauge tube. By the correct choice of the weight of the valve the difference in the heads of water as between a given point in the valve *G* and the water levels in the gauge tube *B* and in the drum is balanced. As the water level in the drum varies, the variation will be transmitted to the hydraulic head pressing on the underside of the valve, and causes corresponding variations in the level of the gauge tube. For a fall in level in the drum the valve tends to sink upon its port *E* and water leaks from the gauge tube *B* until there is a corresponding fall in the gauge tube. When the gauge level tends to fall below that corresponding to the level in the drum *D* then water passes up through the valve and increases the level in the gauge tube. As the level in the drum increases water passes through the pipe *F* and up through the valve *G* and increases the level in the gauge tube *B*, as water can pass from the drum through the pipe *F* and the valve *G* at a greater rate than the water can escape through the port *H*. Thus the valve is constantly in a floating condition whilst the indicator is operating. Alternative designs of indicators for positioning above or below a boiler steam drum are also given in the specification.—*July* 21, 1954.

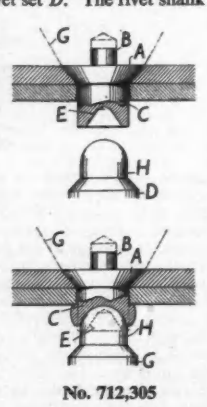


No. 712,249

MISCELLANEOUS

712,305. July 9, 1952.—RIVETING SYSTEMS, Avions Hurel-Dubois, Aérodrome Morane, Route de Verrières, Meudon-Villacoublay (Seine et Oise), France.

As shown in the drawing, the system includes a rivet comprising a head *A* with a centring projection *B*, and a shank *C*, and a rivet set *D*. The rivet shank is provided with a recess *E*, of conical shape, the diameter of this recess at the inlet aperture being equal to about 60 per cent of the outer diameter of the shank *C*. The apex angle of the cone is about 70 deg. and may range from about 65 deg. to 75 deg. This rivet is inserted in the plates to be assembled and is held in position by means of a dolly, as shown at *G*. The rivet set has a semi-spherical end slightly greater, by about 30 per cent, than the diameter of the inlet aperture of the rivet. When the set is forced into the recess of the rivet it causes the hollow portion of the shank to expand, but the expansion of this portion of the rivet is limited to about 30 per cent and is therefore relatively small.—*July* 21, 1954.



No. 712,305

Technical Reports

Natural Air Flow in Industrial Buildings. Research Bulletin No. 3, Melbourne Technical College, Australia.—This work carried out by the department of aeronautical and civil engineering at Melbourne Technical College, is part of a general research project to establish principles of design for the adequate ventilation of industrial buildings by natural means. Measurements of air flow in a small building and its wind tunnel model have been carried out. The results indicate that the ventilation due to wind can be predicted by the testing of a scale model.

The Effects of Inclusions of Imperfections on Magnetisation Processes in Silicon-Iron. (Ref. N/T66.) By L. F. Bates and D. H. Martin. The British Electrical and Allied Industries Research Association, Dorking Road, Leatherhead, Surrey. Price 6s., postage 3d.—Attention is drawn to the important effects which small inclusions such as impurities, or small defects such as accidental or artificially made pits or deformations, may have on magnetisation processes in silicon iron. Two special cases are discussed. In the first, the inclusion is imagined to be wholly within a principal domain. In the second case, a 180 degree boundary passes directly " through " the inclusion.

In Situ Methods of Measuring Soil Moisture Content—A Critical Résumé. (Ref. W/T27.) By B. A. Eastwell, B.Sc. The British Electrical and Allied Industries Research Association, Dorking Road, Leatherhead, Surrey. Price 15s., postage 3d.—A brief account is given of the need for a satisfactory method of determining under field conditions the quantity of moisture present. Methods already developed have been studied in detail and their relative advantages and disadvantages are discussed. The limitations of the tensiometer and the difficulties of calibrating satisfactorily all kinds of soil moisture units are explained and finally suggestions are made for further research on this problem.

Present and Prospective Restriking Voltage Conditions on the British 132kV and 275kV Networks. (Ref. G/T290.) By L. Gosland and J. S. Vosper. The British Electrical and Allied Industries Research Association, Dorking Road, Leatherhead, Surrey. Price 10s. 6d., postage 4d.—The results are given of a comprehensive survey of the inherent restriking voltage characteristics representative of all circuit breaker positions on the British 132kV grid. Limiting curves for the system, both in its present and probable ultimate stages of development, are indicated for three short-circuit MVA levels (namely 1500, 2500 and 3500MVA). An estimation is given of the probable limits for 7500MVA sub-stations on the proposed 275kV network.

Testing of Earth-Continuity Conductors. (Ref. V/T114.) By G. F. Shotter, M.I.E.E., and N. Elliott, A.M.I.E.E. The British Electrical and Allied Industries Research Association, Dorking Road, Leatherhead, Surrey. Price 10s., postage 3d.—The behaviour of joints such as occur in earth continuity conductors is examined in this report, with special reference to existing regulations regarding such conductors and to methods which are or may be employed to test their efficacy. Tests are described both on earth-continuity conductors in service and on simple contact arrangements designed to simulate joints. Reasons are put forward to explain the behaviour observed. As a result recommendations are made for tests which will ensure that an earth-continuity conductor is in a satisfactory condition.

The Magnitude of the Radio Interference in the Television Band from Ignition Systems of Motor Vehicles. (Ref. U/T123.) By A. H. Ball and W. Nethercot. The British Electrical and Allied Industries Research Association, Dorking Road, Leatherhead, Surrey. Price 6s., postage 3d.—British Standard 833 proposes that the magnitude of the ignition interference field should not exceed 50 microvolts per metre when measured under certain defined conditions and with field strength measuring equipment having specified characteristics. Joseph Lucas, Ltd., and the E.R.A. have made measurements on a large number of motor vehicles and the results of these measurements are summarised in this report, which assesses the position relative to the B.S. level of tolerable interference, and shows what degree of suppression is required for compliance with the requirements of B.S. 833.

H.V. D.C. Inverter Stations : Comparison of Cost of Supplying Reactive Volt-Amperes by Various Methods. (Ref. B/T118.) By Dr. Ing. F. Busemann. The British Electrical and Allied Industries Research Association, Dorking Road, Leatherhead, Surrey. Price 12s. 6d., postage 4d.—This report gives an economic comparison of the various means by which the reactive volt-amperes required at an inverter station can be supplied. The cost of the straightforward method of shunt capacitor correction is used as a basis of comparison. The three methods considered, which would appear to cover in principle all the known solutions of this problem, are : series capacitors, forced commutation in one step and forced commutation in two steps. It is concluded that the best solution is obtained by correcting the inverter itself to unity power factor by the use of series capacitors and then providing the reactive volt-amperes required by the a.c. system by means of shunt capacitors. Each of the methods is described and the derivation of the quantities involved is given in detail.

Flameproof Electrical Apparatus : Flanged Joints ¼in in Radial Breadth, in Mixtures of Ethylene Oxide and Air. (Ref. G/T286.) By T. J. A. Brown, B.Sc., A.Inst.P., and N. Simpson. The British Electrical and Allied Industries Research Association, Dorking Road, Leatherhead, Surrey. Price 6s., postage 3d.—For explosive mixtures of ethylene oxide and air, ignited in a bronze sphere having horizontal equatorial flanges ¼in in radial breadth, the most incendive internal mixture is that containing 9·6 per cent of ethylene oxide by volume. The most readily ignitable external mixture contains 8·0 per cent of ethylene oxide. With this combination of internal and external mixtures, the maximum experimental safe gap (M.E.S.G.) on a criterion of $n=20$, $k=0·001$in, is 0·019in, and the statistical maximum safe gap, reassessed, S.M.S.G. (R.) is 0·0123in. The effect of reducing the flange breadth from ¼in is to reduce the M.E.S.G. from 0·026in (Ref. G/T201) to 0·019in, i.e., by 27 per cent; and to reduce the S.M.S.G.(R.) from 0·020in (Ref. G/T279) to 0·012(3)in, i.e., by 39 per cent.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

DIMENSIONS OF GRINDING WHEELS AND SEGMENTS OF GRINDING WHEELS

No. 620 : 1954. Price 6s. This standard supersedes B.S. 620 : 1935 and B.S. 671 : 1936, and in selecting the ranges of wheels to be specified every effort has been made to take account of the developments in grinding practice which have occurred since the earlier standards were published. The principle of simplification has been adhered to, but in order to provide a truly practical standard, the decisions were based on investigations carried out by the Abrasive Industries Association, working in close collaboration with the grinding machine manufacturers. The standard makes several provisions which should be of assistance to users. Tolerances on hole sizes, based on B.S. 1916, " Limits and Fits for Engineering," have been included and recommendations are also made for the drillings for inserted nut discs. Part I of the standard gives dimensions for precision and non-precision wheels for all normal kinds of grinding. For ease of reference, the wheels are grouped according to the various applications. Part II gives shapes and dimensions of segments with particular emphasis on a range of preferred sizes.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASLIB

Fri. to Mon., Sept. 24th to 27th.—Church House, Westminster, London, S.W.1, 29th Annual Conference.

INCORPORATED PLANT ENGINEERS

Wed., Sept. 1st.—LEICESTER BRANCH : Bell Hotel, Leicester, " The Works Engineer and the Factories Act," H.M. District Inspector of Factories, 6.30 p.m.
Tues., Sept. 7th.—LONDON BRANCH : Royal Society of Arts, John Adam Street, London, W.C.2, Open Forum, 7 p.m.
Thurs., Sept. 9th.—NORTH EAST BRANCH : Roadway House, Oxford Street, Newcastle upon Tyne, " The Engineering Application of Electro-Deposited Metals," J. W. Oswald, 7 p.m.
Wed., Sept. 15th.—KENT BRANCH : Bull Hotel, Rochester, Kent, " The Causes and Prevention of Steam Plant Scale," W. F. Gerrard, 7 p.m.——WESTERN BRANCH : Grand Hotel, Bristol, " Planning and Reconstruction of Bristol," R. W. Jeffcott, 7.15 p.m.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS

Tues., Sept. 14th.—Institution of Mechanical Engineers, 1 Birdcage Walk, Westminster, London, S.W.1, " Current American Practice in Heating, Ventilating and Air Conditioning," John K. M. Pryke, 6 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Wed. to Sun., Aug. 25th to 29th.—Ashorne Hill, Warwickshire, Fifth Annual Summer School of Production Engineering.
Wed., Sept. 1st.—NOTTINGHAM SECTION : Visit to the Stanton Iron Works Company, Ltd., Stanton, near Nottingham, 7 p.m.

IRON AND STEEL INSTITUTE

Mon. to Thurs., Sept. 13th to 16th.—IRON AND STEEL ENGINEERS GROUP : 26th Meeting, Newcastle upon Tyne ; the meeting will be devoted to the presentation and discussion of seven papers on the developments at Consett Works, followed by visits to the works at Consett and Jarrow, and the Ore Discharging Terminal at Tyne Improvement Commissioners Quay.